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16. ABSTRACT
The report describes the development of basic procedures that can be used to sample and analyze fugitive (non-stack) emissions from industrial processes, emissions that are a potentially significant portion of the total air emissions in many industries. The development included: identification of the sources of fugitive emissions, evaluation of sampling strategies, preparation of field test procedures, field evaluation of one fugitive emissions field test procedure, and issuance of technical manuals for each sampling strategy. Eighteen industries/processes which might have potentially significant fugitive emissions were identified, selected from all the industries/processes studied and based on the potential of their fugitive emissions to be hazardous and to have high fugitive emissions rates. The 18 industries/processes were grouped by category: metallurgical processing, energy/fuels processing, chemical products, rock products, and agricultural operations.

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DEVELOPMENT OF PROCEDURES FOR THE MEASUREMENT OF FUGITIVE EMISSIONS

by

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FOREWORD

This document constitutes the final report for the work accomplished on EPA Contract No. 68-02-1815, Methods of Measurement of Fugitive Emissions.

The Environmental Technology Division of TRC - The Research Corporation of New England was responsible for the work performed in this program. The work was conducted under the technical and administrative direction of Dr. R. M. Statnick of the Industrial Environmental Research Laboratory, Process Measurements Branch of the Office of Research and Development of the Environmental Protection Agency, which is located at Research Triangle Park, North Carolina. Mr. John E. Yocom, Chief Engineer of TRC, was Program Director and Mr. Peter W. Kalika, Engineering Manager, was project manager. Dr. Robert E. Kenson and Mr. Paul T. Bartlett served as task managers. Major technical contributions were provided by Mr. Don L. Shearer, Mr. William A. Marrone, Mrs. Roberta Huston, Mr. Kevin C. Tower, Miss Nicola F. Grappone, and Miss Jo Anne Marchese.

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1.0 SUMMARY

This document is a final report of EPA Contract No. 68-021815 "Methods of Measurement of Fugitive Emissions." TRC - The Research Corporation of New England conducted the studies undertaken in this program under the supervision and sponsorship of the Industrial Environmental Research Laboratory, Process Measurements Branch of the Office of Research and Development of the Environmental Protection Agency, which is located at Research Triangle Park, North Carolina.

It has been recognized that fugitive (non-stack) emissions from industrial processes are a potentially significant portion of the total air emissions in many industries. The purpose of the program undertaken was to develop basic procedures which could be used to sample and analyze these fugitive emissions. The TRC studies were conducted over a 12-month period between July, 1974, and June, 1975, and divided into the following tasks:

1. Task I - Identify the Sources of Fugitive Emissions. This task consisted of a literature search, a review of TRC experience in fugitive emission measurements, and contacts with industries, regulatory agencies, and industry trade associations. The results are presented in the form of a matrix showing industries, processes, fugitive emission sources, and type of pollutants emitted.

2. Task II - Evaluate Various Sampling Strategies. In this task, TRC considered the application of three broad measurement approaches to the sources listed in the matrix from Task I. Cost and accuracy estimates were made for each of the methods. These approaches are:

   A. Quasi-stack. Here the fugitive emission is temporarily hooded or enclosed and a temporary duct or stack and fans are installed to permit sampling by means of standard stack sampling methods.

   B. Roof Monitor. The term "roof monitor" encompasses a variety of similar situations in which fugitive emissions leave a building or enclosure through roof monitors, roof ventilators, and windows and doors.

C. Upwind-downwind. A carefully designed upwind-downwind sampling network is used under selected meteorological conditions to show the contribution of fugitive sources to ambient air quality. Three dimensional arrays may be needed to permit measurement of pollutant flux past a sampling grid. Mathematical models and tracer studies may be required to describe complex situations.

3. Task III - Prepare a Technical Manual for the Measurement of Fugitive Emissions. Based on Task I and Task II and discussions with EPA, the quasi-stack method was selected for preparation of a test procedures document. A draft was prepared which used as an example case the measurement of fugitive emissions from mold pouring at a gray iron foundry.

4. Task IV - Field Test of a Fugitive Emission Technical Manual. In this task, TRC conducted a field test of the quasi-stack method for mold pouring at a gray iron foundry in southern Connecticut.

5. Task V - Issuance of a Technical Manual. At the completion of the field test program and after all data had been analyzed, the Field Test Procedures Document was thoroughly evaluated by TRC and EPA and modified as appropriate. The approved document was issued as Volume 2 of the final report.

The basic conclusions developed by TRC in this study were:

1. Eighteen industries/processes were believed to have potentially significant fugitive emissions. These were selected from all the industries/processes studied based on the potential of their fugitive emissions to be hazardous and to have high emission rates.

2. The industry or process step/sampling strategy combinations best able to define and measure the fugitive emissions of these 18 industries/processes were identified and studied. This resulted in the specification of three basic sampling strategies (quasi-stack, roof monitor, and upwind-downwind) which could be used to define and measure most of the potentially significant fugitive emissions identified in this program.

3. For the field test portion of this program (Task IV), a quasi-stack sampling strategy was identified as capable of measuring a significant number of fugitive emission sources and as being amenable for implementation within reasonable time and cost

constraints. Mold pouring in a gray iron foundry in Southern Connecticut was chosen as the fugitive emission source for application of the quasi-stack strategy.

4. A quasi-stack sampling strategy was found to be a valid method for studying mold pouring fugitive emissions provided that continuous analysis methods are used and that background pollutant concentrations are separable from those from the operation studied.

As a result of this study, TRC makes the following basic recommendations:

1. EPA should consider further studies of the fugitive emissions of six specific industries.
2. EPA should fund the study of roof monitor and upwind-downwind sampling strategies.
3. EPA should develop specific instrument packages for fugitive emissions.

This report consists of two volumes. One, which is titled, "Methods of Measurement of Fugitive Emissions -- Industrial Fugitive Emissions Sources and Sampling Strategies," documents Tasks I, II, and IV of this study. A second, which is titled, "Technical Manual for the Measurement of Fugitive Emissions -- Quasi-Stack Sampling Method for Industrial Fugitive Emissions," documents Tasks III and V.

2.0 INTRODUCTION

The program was undertaken over a 12-month period between July, 1974, and June, 1975, for the purpose of development of sampling procedures to determine the emission rate and chemical and physical characteristics of fugitive emissions.

It has been recognized that as the emissions from industrial processes through stacks or vents are controlled, by 90 percent, for example, overall process emissions may not be reduced 90 percent. Non-stack or fugitive emissions, which can be produced by almost every industrial process, could become significant portions of the total process emissions. For the purpose of this program, fugitive emissions were defined as those emissions of air pollutants not directed through ducts or stacks and not amenable to measurement by established source sampling methods.

2.1 The Nature of the Fugitive Emission Problem

Almost every industrial operation capable of emitting air pollutants exhibits some fugitive emissions. These emissions vary with the basic process and the manner in which a given process is carried out, e.g., a new cement plant with enclosed raw materials handling and good housekeeping will have far less fugitive dust emissions than an old, poorly operated plant with open storage.

The mechanism for release also varies widely. Fugitive emissions of gaseous pollutants result from:

1. Leaks in piping, packing glands, and other components of process equipment.
2. Exposure of liquids containing a component of appreciable vapor pressure.

3. Exposure of unstable solids, one of whose breakdown products is a gaseous pollutant.
4. Generalized emissions from a building roof monitor or roof fan where many smaller fugitive emissions accumulate within and are vented from the building.
5. Operations carried out outdoors or partially outdoors (e.g., coke charging and pushing).

Gaseous emissions, once they have left the confines of a process and when they are not exhausted through a duct or stack where emission rates can be measured, are fugitive emissions. On the other hand, particulate fugitive emissions, because of gravity and inertial effects, may or may not become fugitive emissions once they have left a process.

Fugitive particulate emissions behave differently from gaseous fugitive emissions. This difference is principally a function of particle size. Particles below about five to 10 microns behave similarly to gases because of their slow settling rate. Above this range of particle size, the settling rate will influence how far a particle will travel and how easily it will become reentrained. Thus, measurements of fugitive particulate emissions must include particle size determinations. In addition, meteorological conditions and the geometry of the release point produce complications in describing the behavior of particulate as compared to gaseous fugitive emissions.

Typical mechanisms for the release of particulate fugitive emissions include:

1. Operations carried on outdoors (e.g., material handling, coke charging and pushing).
2. Particulates formed from the reaction of gaseous fugitive emissions with the atmosphere, moisture, or other gases (e.g., P_2O_5 from phosphorous emissions, and NH_4Cl from adjacent NH_3 and Cl_2 sources).

3. Leaks from confined process streams carrying particulates or condensible vapors (e.g., coke oven door leakages).
4. Outdoor storage of solid materials (e.g., raw material piles, dried sludge beds).
5. Accumulations of dust from inadequate housekeeping which are subject to reentrainment.
6. Traffic on dusty plant roads.

Another factor which complicates the assessment of fugitive particulate matter from an industrial process is the ubiquity of airborne particulate matter as a background component of generalized air quality. Unless the particulate fugitive emission is unique chemically and/or physically and has not already influenced the characteristics of surrounding background particulate matter, it may be difficult to assess the impact of the fugitive emission in question.

2.2 Measurement Techniques

The techniques presently available for measurement of fugitive emissions are:

1. Material Balances
2. Quasi-Stack Sampling
3. Roof Monitor Sampling
4. Upwind-downwind Sampling

Material balance techniques involve no actual tests, but simply determine what enters and exits the process. The material unaccounted for by product or measured emissions is assumed to be the fugitive emission.

The quasi-stack method involves the temporary enclosing, hooding, and ducting of the emission source such that well-established source sampling and analysis techniques can be applied.

The roof monitor method refers to the specialized sampling of fugitive emissions from well-defined building openings such as roof monitors, skylights, ceiling vents, windows, etc.

The upwind-downwind method is generally applied to large outdoor sources and involves carefully designed arrays of samplers upwind and downwind of the suspected fugitive emission source. These samplers can be located both at ground level and at elevated positions. The method involves meteorological measurements which must be related to the samples taken. Diffusion modeling and tracer techniques may also be involved to assist in identifying individual sources of fugitive emissions.

2.3 Scope of Work Undertaken

The program to develop procedures for the measurement of fugitive emissions was divided into the following tasks:

Task I - Identify the sources of fugitive emissions (15 percent of total program effort)

Task II - Evaluate various sampling strategies (15 percent)

Task III - Prepare field test procedures document (10 percent)

Task IV - Field test of fugitive emission field test procedures document (45 percent)

Task V - Issuance of final field test procedures document (15 percent)

This report (Volume I) summarizes the results of Tasks I, II, and IV, as follows:

Section 3.0 - Conclusions based upon the program undertaken
Section 4.0 - Recommendations for further studies
Section 5.0 - Discussion of the procedures and results of the work performed
Appendices - Detailed descriptions of specific methods, references, and detailed matrix charts.

The studies of the "Methods of Measurement of Fugitive Emissions -- Quasi-Stack Sampling Method for Industrial Fugitive Emissions" (Tasks III and V), comprise a separate volume (Volume 2) of this report.

3.0 CONCLUSIONS

The study of industrial sources of fugitive emissions and fugitive emission measurement methods, as well as the field test of a quasi-stack sampling strategy, has led to the following conclusions:

3.1 Industrial Sources

There were 18 industries/processes believed to have potentially significant fugitive emissions. These 18 (Table 3-1) were selected from all those studied based on the potential for their fugitive emissions to be hazardous and to have high emission rates. Other criteria were also used to rank these 18.

3.2 Sampling Strategies

There are three basic sampling strategies suitable for measurement of the fugitive emissions from most potentially significant sources in all the industries studied. These three, the quasi-stack, the roof monitor/enclosure vent, and the upwind-downwind sampling strategies, are described briefly in Table 3-2, including their limitations and general accuracy ranges.

3.3 New Methods

For some significant fugitive emission sources, present sampling strategies may be inadequate. An example was the copper smelting industry, where openness of building structures limits present sampling strategy application. New developments in remote sensing were seen as potentially useful tools in this application.

TABLE 3-1

CLASSIFICATION OF INDUSTRIES FOR POSSIBLE FUTURE STUDIES OF FUGITIVE EMISSIONS

Category	Industry/Process
Metallurgical	Primary Aluminum Primary Copper Electric Furnace Steel Iron & Steel Foundries Coke Making
Energy/Fuels	Coal Mining Coal Gasification COG (Char-Oil-Gas) Shale Oil Petroleum Refining Oil Production
Chemical Products	Plastics Tire & Rubber
Rock Products	Phosphate Fertilizer Lime Sand & Gravel Asphalt Batching
Agricultural Operations	Cattle Feedlots Soil Tilling Grain Harvesting

TABLE 3-2

EVALUATION OF CANDIDATE STRATEGIES FOR MEASURING FUGITIVE EMISSIONS

Candidate Strategy	Requirements	Applicability	Absolute Accuracy	Relative Accuracy
1. Roof-Monitor/Enclosure Vent Strategy (Use of Available Enclosures such as Buildings	1. Openings must be regular and amenable to sampling for concentration and air flow. Impractical if too many openings.	1. Buildings housing multiple units which have fugitive emissions - Cl_2 caustic cells, aluminum pots, electric furnaces, etc.	± 25%	± 25%-50%
	2. Ventilation (natural or power) must be such that a material blance can be established.	2. Buildings containing materials storage which emits pollutants while stored, e.g., synthetic fertilizer, odors from rendering.		
	3. If natural ventilation exhausts the fugitive emissions, enough data must be taken to establish emissions under a variety of meteorological conditions.	3. Buildings containing a variety of materials handling and processing operations.		
2. Quasi-Stack Sampling Strategy (Construction of special enclosures with off take duct for sampling.)	1. Enclosure must capture essentially 100% of fugitive emissions.	1. Can be applied to a wide range of relatively small operations such as welding, solvent etc.	± 25%	± 25%
	2. Enclosure must not affect emission rate or physical and chemical characteristics of emissions.	2. Can be used for measuring leaks from piping, packing glands, etc.		
	3. The scale of the fugitive emissions may be too great for construction of a reasonably sized enclosure.	3. This method where applicable can provide quite accurate results.		
3a Upwind-Downwind Strategy (Simultaneous Upwind-Downwind sampling.)	1. Fugitive emissions must be unique and identifiable in relation to, or not influenced by, other plant emissions.	1. Must be applied when two previous strategies cannot be used.	± 50%	± 500%
	2. Sampling array must encompass the fugitive emissions cloud and provide enough detail to establish concentrations across the entire cloud.	2. Applicable where fugitive emissions of the same type are emitted from several areas of a plant.		
	3. Wind flux measurements are needed at several points both laterally and longitudinally in the cloud path.			
3b Upwind-Downwind Strategy (Upwind-Downwind sampling together with diffusion modeling and tracer studies.)	1. Model must be applicable to fugitive emission points.	1. Applicable where the preceding three strategies cannot be used alone.	± 50%	± 200%
	2. Detailed micro-meteorological data are required.	2. Applicable where various types of fugitive emissions are present and where background pollutants influence measurements		
	3. Field measurements must be carried out under specified meteorological conditions.			

3.4 Cost-Effectiveness

The cost-effectiveness of each sampling strategy when applied to a specific source varied considerably. For different sources, different optimum sampling strategies could be found. It was found that cost-benefit tradeoffs could be examined for each of the three fugitive emission sampling strategies by developing error limits vs. cost curves for selected fugitive emission sources.

3.5 Quasi-Stack Strategy

The quasi-stack sampling strategy was identified as being widely applicable to many significant industrial fugitive emission sources, and as an excellent candidate for field tests. It has generally acceptable accuracy limits and in many cases can be made cost-effective. It was found to be a valid method for the study of mold pouring emissions provided that continuous analysis methods are used and certain other criteria are met. These other criteria include:

1. Background pollutant concentrations are separable from the operation studied.
2. Physical location of sampling allows proper positioning of required equipment and isolation of the test area from other plant operations.
3. Sampling times where significant fugitive emissions will occur are compatible with instrument response times.
4. Sample concentrations are within the analysis capability of the instruments.
5. The quasi-stack configuration can be designed to capture all of the fugitive emissions to be studied without serving as a general ventilation hood for all in-plant pollutants, or otherwise biasing pollutant concentrations or characteristics.

3.6 Alternative Strategy

As an alternative to the quasi-stack sampling strategy in an iron foundry or similar situation, a roof monitor sampling approach would be applicable under certain conditions, which include:

1. High background pollutant concentrations prevent separation of any single pouring or other operation.
2. Physical limitations prevent setup or isolation of a quasi-stack sampling area.
3. Response times of instruments prevent capture or display of single event fugitive emissions.
4. Sample concentrations from single events are below the instrument threshold.
5. The quasi-stack configuration cannot be used for emission capture and the building structure is well enclosed and has well defined vents.

3.7 Method Limitations

Standard particulate measurement techniques (time-averaging methods such as filter collection) may be unsuitable for fugitive emission studies, especially where emissions are transient in nature and release is over a short time duration.

4.0 RECOMMENDATIONS

TRC, on the basis of its studies of fugitive emissions under EPA Contract 68-02-1815, makes the following recommendations:

4.1 Industry Studies

EPA should consider further studies of the fugitive emissions from some of the industries listed in Table 3-1. In particular, the industries most in need of study would be:

1. Primary copper
2. Coke making
3. Electric furnace steel
4. Petroleum refining
5. Coal gasification
6. Iron and steel foundries (continue and expand work begun in this study)

This listing is based upon both the mass rate and the hazardous nature of their fugitive emissions. In particular, the fugitive emission potential of a significant new energy process, coal gasification, should be examined in detail. The impact of this industry on air quality in the future could be significant, and an important part of this impact could be the fugitive emissions.

4.2 Strategy Tests

EPA should fund the study of the roof monitor and upwind-downwind sampling strategies for fugitive emission measurement. A comparison of all three major strategies could then be made after field test of these fugitive emission sampling methods.

4.3 New Methods

EPA should consider funding of research in the application of remote sensors for the study of fugitive emission sources. For some potentially significant sources, the three major strategies are inadequate. This research might be conducted in parallel with field tests of either the roof-monitor or upwind-downwind strategies to attempt correlation.

4.4 Documentation

EPA should develop a fugitive emissions measurement handbook. This would outline sampling strategies available to the investigator, including a basic methodology and procedures. By use of a multi-volume format, annual updates would be possible as technology advances.

4.5 Package Development

EPA should develop instrumentation packages designed to measure fugitive emissions. Although they may not be adopted as standard EPA methods, they could be presented as EPA-recommended methods. This would help standardize fugitive emission measurements and aid in the development of correlations between investigators, including better estimates of relative and absolute errors. These may include remote sensing methods.

4.6 Impact Determination

EPA should consider the special needs of fugitive emission impact estimation procedures. Since present stack plume models may need modification to be used for the simulation of the impact on ambient air of fugitive emissions, a comprehensive study program may be required in this area. TRC studies of the impact of fugitive sources on ambient air quality has shown that estimation of the source strength, source height, and diffusion rate of the fugitive pollutants from open sources, open vent/roof monitor sources, or even short stack sources can be considerably in error unless examined in some detail and appropriate modifications made in the diffusion models. This would aid EPA efforts in many areas of study, where fugitive emission impacts up to now have not been considered.

4.7 Refinement of Quasi-Stack

EPA should sponsor research to refine quasi-stack fugitive emission measurement methods. The limitations found by TRC in its field studies, especially with regard to time intervals of fugitive emissions and their variability and isolability, point out areas for further development. Extensive testing of various continuous monitors, especially for particulate matter mass rate and particle size, may be required.

5.0 DISCUSSION

The overall objective of the program was to develop methods for the measurement of fugitive emissions of air pollutants from several industrial processes. Fugitive emissions, for the purposes of this study, were defined as those emissions of air pollutants which are not directed through ducts or stacks and which are not amenable to measurement by established source sampling methods. The methods developed under this program were to be adequate for quantifying fugitive emissions within reasonable and calculable error limits and capable of use for assessing measures designed to control fugitive emissions.

A five task program to accomplish this was conducted as follows:

5.1 Task I - Identify the Sources of Fugitive Emissions

In order to identify possible industrial sources of fugitive emissions, a four part program was conducted with the following results:

5.1.1 Literature Search for Sources

A bibliography of references specifically directed to fugitive emissions was developed and is presented in Appendix A. The key documents used to develop the fugitive emission data for industries believed to have significant fugitive emission potential are included. A substantial number of the key documents were EPA research project reports wherein overall process emissions and in some cases fugitive emissions were quantified. Only recently have any significant number of fugitive emission studies been reported in the open literature.

Another source of fugitive emission information was TRC in-house information developed during studies for industrial and governmental clients. Table 5-1 summarizes these. Because of their confidential nature (with a few exceptions), it was not possible to cite these in the bibliography. They are a substantial body of information, especially in regard to fugitive emission measurement methods.

5.1.2 Trade Association/Industry/Government Agency Contacts

Six trade associations and two companies were contacted to obtain information concerning fugitive emissions in industries of potential interest. Four of these contacts have supplied data which will be useful in identifying and quantifying fugitive emissions. Six air pollution control agencies were contacted but no "hard" data were obtained from them. Appendix B summarizes all the contacts which were made. The contacts made did have an appreciation for the fugitive emission potential of the industrial processes with which they were familiar. However, in common with many others, they had for the most part not conducted studies of fugitive emissions because of the priorities which have had to be given to the characterization and control of stack emissions. One exception to this was the contact with Dr. Fred Templeton, Assistant to the President of the Metal Mining Division of Kennecott Copper. Dr. Templeton supplied EPA and TRC with fugitive emission data developed by Dr. John Heaney of the Utah Copper Division of Kennecott Copper. These data, in conjunction with those available from other sources, were used to develop a matrix chart which describes most of the fugitive emission factors for the copper smelting industry. Table 5-2 summarizes these emission

TABLE 5-1

SUMMARY OF TRC STUDIES RELEVANT TO FUGITIVE EMISSIONS MEASUREMENT

	Client Category	Fugitive Emission Studies Done
1.	Iron and Steel Works	Welding operations gas and particulate emissions
2.	Inorganic Chemical	Emissions of dust from ground, materials handling and storage piles in plant.
3.	Steel Company Coke Works	Smoke emissions from leaking doors and coke pushing and charging
4.	Municipal Health Department (Report on Proposed Iron & Steel Works)	Contribution of dust emissions from proposed plant on local air quality. Similar plant emission data and diffusion model used for prediction
5.	Inorganic Chemical Company	Dust emissions from uncontrolled vents and from open windows of dry bleach plant
6.	ASHRAE (Research Project TRP-93)	Use of air conditioning equipment to reduce outdoor air pollutants drawn into buildings
7.	USPHS, DHEW, NAPCA Contract CPA-22-69-14	Leakage of emissions inand out of structures such as houses. Measurement of fugitive emissions from stoves, etc.
8.	Assembly Plant Electric Components	Solvent emissions from coating operations where concentrations vary.
9.	EPA Contract CPE-69-5	Study of emissions from disposal of solid wastes
10.	Cement Company	Upwind and downwind particulate emission measurement to determine plant contribution
11.	Cement Company	Upwind and downwind particulate emission measurement plus diffusion modeling
12.	Sinter Plant in Steel Mill	Analysis of local air quality and contribution of sinter plant emissions to this. Used up and downwind measurements.
13.	Iron Foundry	Contribution to particulate emissions of unpaved parking lot
14.	Rubber Manufacturing	Uncontrolled curing press emissions measured
15.	Turbine Manufacturing	Fuel and Solvent transfer system emissions
16.	Rubber Manufacturing	Emissions inventory of uncontrolled sources in tire plant
17.	Parking Garage	Dispersion modeling to determine CO concentrations at peak times
18.	Gravel Pit	Air quality measurements of particulates from fugitive and other sources
19.	Coke Works	Air quality measurements in plant including those near fugitive sources
20.	EPA Contract 68-02-0047	Evaluation of particulate control strategies which include fugitive emissions from demolition

TABLE 5-2

MATRIX CHART OF FUGITIVE EMISSION SOURCES IN COPPER SMELTING

Process Step	Particulate Fugitive Emissions		Gaseous Fugitive Emissions	
	Mass Rate	Composition (Approximate)	Mass Rate	Composition (Approximate)
1. Ore Concentrate Storage and Handling	↑	Cu 28%(3) Fe 24% S 32% SiO_2 11% Other 5%	Unknown	Unknown
2. Limestone Storage and Handling		CaO ∿ 60%	Unknown	Unknown
3. Slag Handling	10 lbs/ton(3) Copper	Cu 0.5%(3) Fe 40% SiO_2 38% S 1.5%	0.4 lbs.S(1) /Ton Slag	Unknown
4. Dust Collection and Transfer	↓	Unknown	Unknown	Unknown
5. Roaster Loading and Operation	↑	Cu 5%(4) Zn 16% Cd 0.5% Pb 18% As 60% 70%<2μm	↑	SO_x-5-6%(4) SO_x-5-15%(3,5)
6. Calcine Transfer	2.0 Tons/ Day(1)	Unknown	5.2 Tons/ Day SO_2 (1)	Unknown
7. Reverberatory Furnace Loading and Operations		Cu 5%(4) Zn 16% Cd 0.5% Pb 18% As 60% 70%<2μm		SO_x-5-6%(4) SO_x-1-3%(3,5)
8. Matte Transfer	↓	Cu 42%(3) Fe 32% SiO_2 1% S 25%	↓ 8.3 lbs.S(2) /Ton of Matte	Unknown
9. Converter Loading and Blowing	↑ 4-5 Tons/ Day(3)	Cu 1%(4) Zn 8% Cd 4% Pb 50% As 37% 10%<2μm	↑ (1) 35-40 Tons/ Day SO_2	SO_x-1-5-4%(4) SO_x-14-19%(3)
10. Blister Copper Transfer	↓		↓ 3.5 lbs.S(2) /Ton Cu	Unknown

(1) Utah Copper Division Data Supplied by Kennecott Copper Corporation.

(2) Noranda Mines Ltd. Data Supplied by Kennecott Copper Corporation.

(3) "Systems Study for Control of Emissions - Primary Non-Ferrous Smelting Industry" Arthur G. McKee and Company NTIS Report No. PB 184 884.

(4) Measurement of Sulfur Dioxide, Particulate and Trace Elements in Copper Smelter Converter and Roaster Reverberatory Gas Streams, EPA Report No. 650/2-74-11 by Control Systems Laboratory

(5) Air Pollution Control Technology and Costs in Nine Selected Areas, IGCI Report on EPA Contract 68-02 0301

(6) Emission includes all these operations.

factors.

Mr. Tom Keller of Bethlehem Steel contributed information on roof monitor emission measurement techniques. Although not used as a sampling strategy in the field test program, this information offered valuable guidelines for conducting such tests in the future.

5.1.3 Matrix Charts for Identification of Selected Industries

A list of possible industries and processes which might have fugitive emissions was developed. To identify where these occur, a matrix chart was evolved which lists vertically the industry or process studied and horizontally the operations which make up these industries or processes. These were provisions on the charts for symbols to characterize the type of fugitive emission encountered. Appendix C shows these charts.

The completed matrix charts were used as a basis for selection of industries which might involve significant fugitive emissions. A list of 18 such industries was developed and the matrix charts of these industries were consolidated. These industries were reviewed in more depth so that the list would be refined to identify the most serious candidate industries for fugitive emissions testing. Tentative sampling strategies concepts were developed for these 18. Table 5-3 identifies the industries and their major potential fugitive emission problems.

In the absence of "hard" data, mass rates of fugitive emissions were estimated not in terms of absolute numbers but in terms of their potential fraction of total air emissions. Where the potential fraction was high (> 10 percent), the industry or process might be worthy of further study. Industries with potential for release of low TLV and/

TABLE 5-3

CLASSIFICATION OF INDUSTRIES FOR POSSIBLE FUTURE STUDIES OF FUGITIVE EMISSIONS

Category	Industry/Process	Major Fugitive Emissions
Metallurgical	Primary Aluminum	Fume, Fluorides, PNA's
	Primary Copper	Fume, SO_2, Dust
	Electric Furnace Steel	Fume, Kish, CO, Odors
	Iron & Steel Foundries	Fume, Odors
	Coke Making	Hydrocarbon Fumes, Odors, CO, PNA's
Energy/Fuels	Coal	Dust
	Coal Gasification	Hydrocarbon Fumes, CO, PNA's
	COG (Char-Oil-Gas)	Hydrocarbon Fumes & Vapors, CO, PNA's
	Shale Oil	Dust, Hydrocarbon Fumes & Vapors, CO, PNA's
	Petroleum Refining	Hydrocarbon Vapors, Odors, PNA's
	Oil Production	Hydrocarbon Vapors, Odors
Chemical Products	Plastics	Hydrocarbon Vapors, Odors
	Tire & Rubber	Hydrocarbon Vapors, Odors
Rock Products	Phosphate Fertilizer	Dust, Fluorides, SO_2
	Lime	Dust
	Sand & Gravel	Dust
	Asphalt Batching	Dust, Odors, PNA's
Agricultural Operations		Dust, Odors

or known carcinogenic materials were considered for further study. Highly reactive or toxic fugitive emissions also help to place an industry on this list.

The 18 industries selected for possible study could be reduced to four categories (see Table 5-8): metallurgical, fuels/energy, chemical products, and rock products. Only one industry escaped classification in Table 5-3: agricultural operations. It was important, however, that this category be studied, since its fugitive dust problems had significant impact on measurements of particulate emissions in other industries such as rock products. The state of Colorado, for example, cannot meet particulate matter primary air quality standards because of agricultural contributions.

5.1.4 Fugitive Emission Sampling Techniques and Strategies

A scanning of the literature on sampling techniques showed that few new techniques have been developed for measurement of fugitive-type emissions. Appendix D summarizes specific references found. One advance was the development of a procedure for sampling emissions from roof monitors. This procedure is more of a refinement of a technique previously used rather than a new sampling technology. Much the same can be said about the other measurements mentioned in the literature.

Our new development indicated that lidar (light detection and ranging/laser radar) might be applicable to measurement of fugitive dust emissions. It has two possible advantages: readings are instantaneous and a large number of accurate mappings of fugitive dust cloud might be obtainable in the time needed for one such set of data from a standard particulate sampling test array. There are two possible disadvantages: commercial models may not be readily available and we are not aware of any present studies which seek to confirm direct applicability to the type or problems encountered in fugitive dust measurements (most work has been done with lidar used in stack plume mapping).

The 18 industries/processes of interest for possible fugitive emissions studies were closely examined to see which sampling strategy might be applied to each of the suspected fugitive emission sources. If more than one strategy or a combination of strategies might be appropriate, this was noted. An attempt was also made to rate the strategy as to its applicability.

The sampling strategy/industry or process combinations considered to be feasible are given in Table 5-4.

In all cases, a feasible sampling strategy was found for each industry/process of possible future interest for fugitive emission studies. In some cases, however, there were serious limitations to the applicability of the proposed sampling strategy and it is apparent that alternate new or new combinations of older sampling strategies should be investigated.

The most universally applicable sampling strategy for outdoor sources was found to be the upwind-downwind technique. In 16 of the 18 industries/processes of interest, this strategy would adequately quantify most of the major outdoor fugitive emissions encountered. There are limitations in that tracers and/or diffusion modeling might have to be done in conjunction with sampling in order to obtain accurate results. Elaborate sampling systems may be required and considerable total sampling time may be required for the definition of each fugitive source, which can be a

TABLE 5-4

FEASIBLE SAMPLING STRATEGIES FOR INDUSTRIES/PROCESSES SELECTED FOR POSSIBLE FUGITIVE EMISSIONS STUDIES

Industry/Process	Critique of Sampling Indoor Fugitive Emissions	Strategy For: Outdoor Fugitive Emissions
Primary Aluminum	Roof Monitor/Enclosure Vent is ideal.	Upwind-Downwind Acceptable
Primary Copper	Roof Monitor/Enclosure Vent limited in accuracy because buildings too open. Quasi-Stack may be used.	Upwind-Downwind requires tracers and complicated sampling.
Electric Furnace Steel	Roof Monitor/Enclosure Vent plus Quasi-Stack are ideal.	Slag expansion might require Quasi-Stack. Upwind-Downwind acceptable.
Iron & Steel Foundries	Roof Monitor/Enclosure Vent plus Quasi-Stack are ideal.	Upwind-Downwind has problems but acceptable for open buildings.
Coke Making	None	Upwind-Downwind requires tracers and complicated sampling. Quasi-Stack may isolate individual sources but there are many of them.
Coal	None	Upwind-Downwind useful, but fires in waste piles may defy analysis. Quasi-Stack may also be used to point sources.
Coal Gasification	Maybe indoors to some extent, then Roof Monitor/Enclosure Vent or Quasi-Stack would be applicable.	Same problems as Coke Making.
COG (Char-Oil-Gas)	Maybe indoors to some extent, then Roof Monitor/Enclosure Vent or Quasi-Stack would be applicable.	Same problems as Coke Making.
Shale Oil	Maybe indoors to some extent, then Roof Monitor/Enclosure Vent or Quasi-Stack would be applicable.	Same problems as Coke Making.
Petroleum Refining	None	Upwind-Downwind would appear to be feasible. Would be difficult to isolate individual sources, however Emissions Inventory can be used also. Quasi-Stack can apply to point sources.
Oil Production	None	Upwind-Downwind would appear to be feasible. Would be difficult to isolate individual sources, however, Emissions Inventory can be used also.
Plastics	Roof Monitor/Enclosure Vent plus Emission Inventory would be ideal combination.	Upwind-Downwind acceptable.
Tires & Rubber	Roof Monitor/Enclosure Vent plus Emission Inventory would be ideal combination.	Upwind-Downwind acceptable.
Phosphate Fertilizer	Quasi-stack may be used inside.	Upwind-Downwind limited because of number of sources involved. Consider remote sensing.
Lime	None	Upwind-Downwind limited because of number of sources involved. Consider remote sensing.
Sand & Gravel	None	Upwind-Downwind limited because of number of sources involved. Consider remote sensing.
Asphalt Batching	None	Upwind-Downwind limited because of number of sources involved. Consider remote sensing. Quasi-stack for hydrocarbons.
Agricultural Operations	None	Only methods are Upwind-Downwind and Quasi-Stack.

problem if many are present in one industry/process, and if operating cycles are short.

The possibility of remote sensing which would allow short time interval mapping of fugitive dust clouds or gas emissions should be considered as an alternate sample strategy. One example where this might be a good choice would be at a copper smelter. Lidar could be used to map the particulate matter fugitive dust clouds from storage piles and building openings and a correlation spectrometer could be used to map fugitive SO_2 emissions.

The other two strategies which have been considered have about equivalent applicability to fugitive emission sources. The quasi-stack and roof monitor/enclosure vent strategies measure fugitive emissions which can be directed into and vented through specific openings or enclosed areas. This makes them ineffective in determining fugitive emissions from outdoor sources, such as storage piles or process steps such as crushing and grinding of gravel, lime, etc., where the operation is accomplished in an open-sided structure or entirely in the absence of an enclosing structure. However, for many metallurgical processes which occur inside buildings, such as aluminum electrolysis or electric furnace steel making, these techniques are ideal for measurement of fugitive emissions.

It can be concluded that, although adequate concepts of sampling systems and analytical methods for fugitive emissions measurements can be specified for all the industries currently of potential interest on this project, there is obviously room for improvement. It appeared that it would be advantageous to continue through Task II some additional literature search effort directed toward finding new fugitive emission sampling methods. It also appeared at this juncture that any of the three strategies mentioned above would be a good choice for most significant cases of fugitive emissions.

5.2 Task II - Evaluating Various Sampling Strategies

Task II was divided into a series of subtasks. These subtasks, which followed in logical sequence from Task I, can be described as follows:

5.2.1 Evaluating 18 Selected Industries

The criteria used for development of the original 18 industry list were:

1. Large number of fugitive emission sources
2. Large mass rate of fugitive emissions
3. Large number of plants extant in the United States
4. Industry found near urban areas.

The list was reviewed for the purpose of rating the industries for overall fugitive emissions potential and also the steps within them which might exhibit major fugitive emissions so that the list could be further culled. The criteria applied were the above four plus the following:

5. Hazardous nature of gaseous fugitive emissions
6. Particle size of particulate fugitive emissions (respirability)
7. Hazardous nature of particulate fugitive emissions
8. Probability of control of fugitive emissions by new technology in the immediate future.

A rating system was therefore used as a guide to aid in the selection of the final candidate industries, but this was not the only process used to select these industries. It was not possible to rank the industries/processes in direct numerical order of the seriousness of their fugitive emissions. This was dictated by the nature of the fugitive emission sources, which makes it difficult to quantify the emission rate and identify the components of that emission. Table 5-5 shows how the ratings were arrived at for the 18 industries.

5.2.2 Suitability of Sampling Strategies

Another subtask involved evaluation of the suitability of the proposed basic sampling strategies to measure fugitive emissions of the process steps of the 18 industries where fugitive emissions were considered significant. This was done by developing a matrix (Table 5-6, for example), listing for each of the industries/processes the process steps believed to have significant fugitive emissions, the nature of the gaseous and particulate fugitive emissions, and the basic sampling strategy most applicable to the fugitive emissions of the step. A process flowsheet was also developed or extracted from the literature. Figure 5-1 is an example.

5.2.3 Evaluate Sampling Analysis Techniques

The procedures of subtasks 1 and 2 pointed out there existed substantial commonality in sampling and analysis requirements from industry to industry. There was an obvious need to specify the best sampling/analysis techniques which might be applied to the measurements of fugitive emissions, but these techniques would also need to be compatible with the technical requirements and the financial resources of each sampling strategy to which they would be applied.

TABLE 5-5

METHOD OF RATING HAZARD POTENTIAL OF FUGITIVE EMISSIONS OF 18 SELECTED INDUSTRIES

Industry or Process	Criterion								Average
	A	B	C	D	E	F	G	H	
1. Primary aluminum	4	4	4	3	4	4	4	2	3.6
2. Primary copper	5	5	3	3	4	4	5	4	4.1
3. Electric furnace steel	3	4	5	5	3	4	4	3	3.9
4. Iron and steel foundries	4	4	5	5	4	4	3	3	4.0
5. Coke making	5	5	3	5	5	5	5	3	4.5
6. Coal	5	4	4	1	1	3	3	3	3.0
7. Coal gasification	5	4	(4)	2	5	5	5	3	4.1
8. COG	5	4	(2)	2	5	5	5	3	3.9
9. Shale oil	5	4	(2)	2	5	5	5	3	3.9
10. Petroleum refining	5	4	3	4	3	4	4	4	3.9
11. Oil production	3	3	3	2	3	4	4	4	3.3
12. Plastics	4	3	5	5	4	3	3	3	3.8
13. Tire and rubber	4	3	3	5	4	3	3	3	3.5
14. Phosphate fertilizer	4	4	3	3	3	4	3	2	3.3
15. Lime	2	5	5	3	2	2	2	4	3.1
16. Sand and gravel	2	5	5	3	2	2	2	4	3.1
17. Asphalt batching	2	3	5	3	4	3	5	3	3.5
18. Agricultural operations	5	2	5	1	1	2	2	5	2.9

( ) = Future Estimates

A	Large number of fugitive emission sources
B	Large mass rate of fugitive emissions
C	Large number of plants extant in the United States
D	Industry found near urban areas
E	Hazardous nature of gaseous fugitive emissions
F	Particle size (respirability) of particulate fugitive emission
G	Hazardous nature of particulate fugitive emission
H	Probability of control of fugitive emissions by new technology in the immediate future

(Highest number rates worst)

TABLE 5-6

MATRIX OF IRON AND STEEL FOUNDRIES FUGUTIVE EMISSION SOURCE/SAMPLING STRATEGY COMBINATIONS

Operation	Particulate	Gas and Vapor Emissions	Sampling Strategy
Coke, silica, sinter, scrap delivery and storage	Dust**		Upwind-downwind or Quasi-stack
Furnace or cupola* charging	Fume** Carbon-dust** Smoke (oil)**	CO** Hydrocarbons	Quasi-stack or Roof Monitor
Melting	Fume** Dust**	CO**	Quasi-stack or Roof Monitor
Tap and pour slagging	Fume**	Hydrocarbons** (odors) CO,** SO_2, H_2S	Quasi-stack
Mold pouring*	Dust**	Hydrocarbons** (odors) CO,** PNA**	Quasi-stack
Product finishing	Dust**	SO_2, CO	Quasi-stack
Pollution control equipment dust transfer and storage	Dust**		Upwind-downwind or Quasi-stack

*Most critical steps for fugitive emissions
**Most significant fugitive emissions

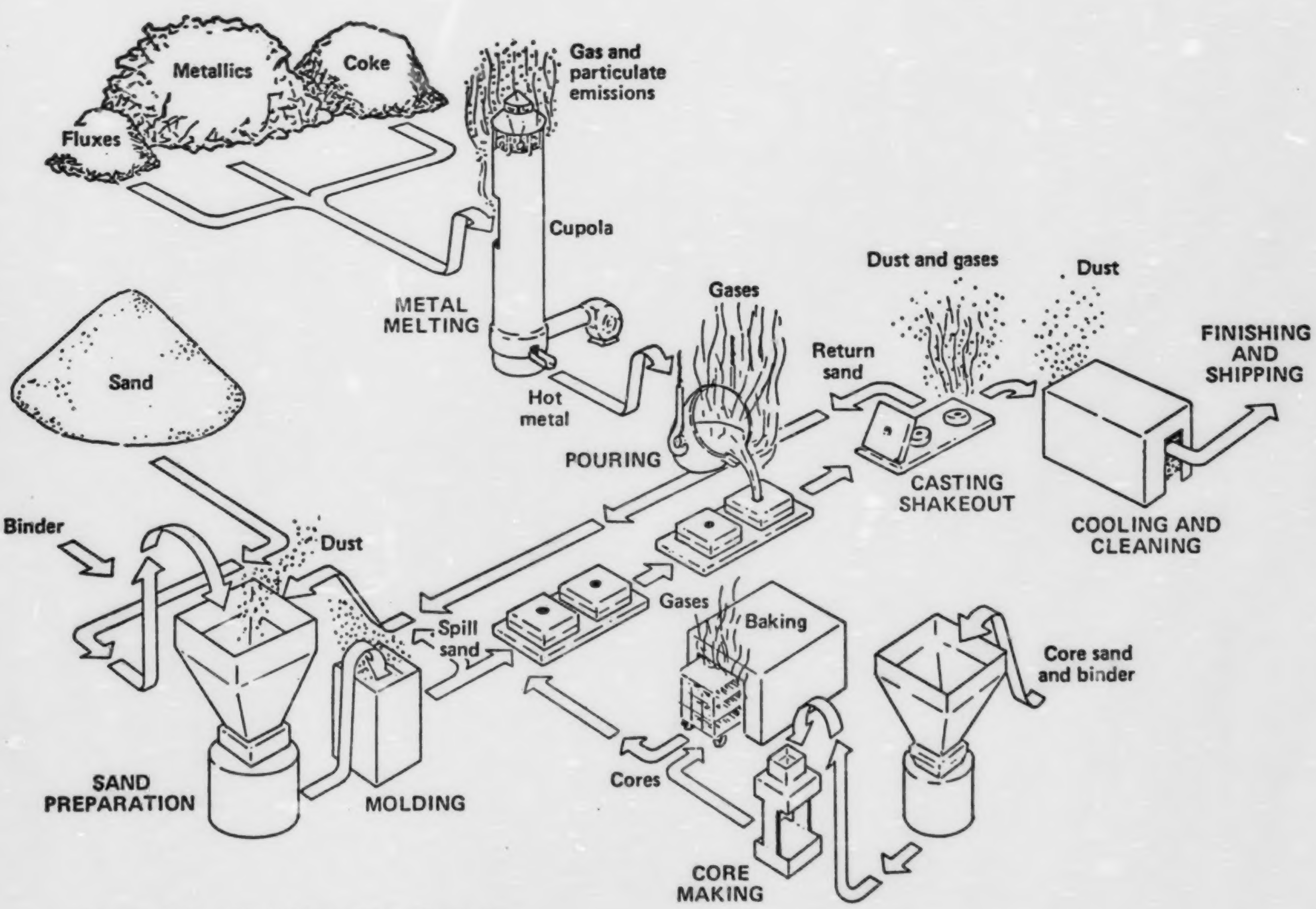

Metallics
Coke
Fluxes
Gas and particulate emissions
Cupola
METAL MELTING
Hot metal
Sand
Gases
POURING
Return sand
Dust and gases
Dust
FINISHING AND SHIPPING
CASTING SHAKEOUT
COOLING AND CLEANING
Binder
Dust
Spill sand
Gases
Baking
Core sand and binder
SAND PREPARATION
MOLDING
Cores
CORE MAKING

Figure 5-1: Simplified Flow Sheet for Gray Iron Foundry

An in-depth evaluation or critique of certain sampling/analysis techniques was therefore undertaken in the areas of:

1. Hydrocarbon analysis (gaseous and particulate)
2. Fluorides analysis (gaseous and particulate)
3. Total suspended particulates analysis (size distribution, chemical nature, continuous analysis)
4. Sulfur compounds analysis (identification, continuous analysis)
5. Remote sensing (particulates or gas, continuous analysis)

One of these critiques is included as Appendix E. These critiques aided in evaluation of sampling strategies and they were also very important in the preparation of a suitable field test procedure in Task III.

5.2.4 Selection of Sampling Strategy/Industry Combinations for Further Evaluation

An evaluation was made to establish the most common basic sampling strategy/industry source combinations in the 18 industry list. This was accomplished by first establishing a matrix of 23 strategy/source combinations which would cover all or most of the significant fugitive emission sources found on the 18 industry list. From this a determination was made of how many of these were related well enough to list common combinations. This final matrix of four general combinations, which also provides the first step of Task III, is shown in Table 5-7. It includes some additional elements which relate to Task III.

This list of four was jointly reviewed by TRC and EPA, and led to the choice for preparation of a test procedure and field demonstration of a quasi-stack sampling strategy.

TABLE 5-7

MATRIX OF FINAL SELECTIONS OF FUGITIVE EMISSIONS
SAMPLING STRATEGY/INDUSTRY SOURCE COMBINATIONS

Fugitive Source Sampling Strategy	Industry Applied To	Process Step Involved	Other Industries Where Applicable	Fugitive Emissions		Nature of Fugitive Emissions Measured
				Mass Rate	Hazardous Nature	
			Specific			
1. Upwind-Downwind	Coal Gasification	Reactors Charge & Discharge & Storage Of Coal	Coal Gasification	Med. to High	PNA's. Reactive Hydrocarbons	Particulates: A. Size Dist. B. Mass C. Composition D. Organics (PNA) Hydrocarbons CO Sulfur Gases Phenols Pyridines NH_3
			Petroleum Refining	Med. to High	PNA's "	
			Oil Production	Med. to High	" "	
			Shale Oil Product	Med. to High	" "	
			Char-Oil-Gas Prodn.	Med. to High	" "	
			Asphalt Batching	High	PNA's only	
			General			
			Coal Preparation			
			Phosphate Fert.			
			Lime			
			Sand & Gravel			
			Specific			
2. Roof Monitor	Primary Aluminum	Potroom	Primary Aluminum	Med. to High	Fluorides, PNA's, Small Metallic Particulate	Particulates: A. Size Dist. B. Mass C. Composition E. Organics (PNA) Hydrocarbons CO Sulfur Gases Fluorides A. Gas B. Particulate
			Primary Copper	High	SO_2, Small Metallic Particulate	
			Elec. Furnace Steel	Med. to High	Fluorides, Small Metallic Particulate	
			Iron & Steel Found.	Med. to High	PNA,s, Small Metallic Particulate	
			General			
			Phosphate Fert.			
			Plastics			
			Tire & Rubber			
			Specific			
3. Quasi-Stack	Iron & Steel Foundries	Cupola Charging	Iron & Steel Found.	Med. to High	Reactive Hydrocarbons, Metal Particulate	Particulates: A. Size Dist. B. Mass C. Composition D. Organics (PNA) Hydrocarbons CO Sulfur Gases Fluorides A. Gas B. Particulate
			Elec. Furnace Steel	Med. to High	" " " "	
			Primary Copper	Very High	SO_2, Metal Particulate of Small Size	
			Primary Aluminum	Med. to High	PNA's, Metal Particulate of Small Size	
			General			
			Asphalt Batching			
			Phosphate Fert.			
			Plastics			
			Tire & Rubber			
			Lime			
			Coal Gasification			
			Coke Making			
			Shale Oil Prodn.			
			Specific			
4. Quasi-Stack	Iron & Steel Foundries	Mold Pouring	Iron & Steel Found.	Medium	PNA's, Hydrocarbons, Metal Particulates of Small Size	Particulates: A. Size Dist. B. Mass C. Composition D. Organics (PNA) Hydrocarbons CO Sulfur Gases Fluorides A. Gas B. Particulate Odors
			Elec. Furnace Steel	Medium	Metal Particulates of Small Size	
			Primary Copper	Medium	SO_2 Metal Particulates of Small Size	
			Primary Aluminum	Medium	PNA's, Metal Particulates of Small Size	
			General			
			Asphalt Batching			
			Phosphate Fert.			
			Plastics			
			Tire & Rubber			
			Lime			
			Coal Gasification			
			Coke Making			
			Shale Oil Prodn.			

5.2.5 Cost-Effectiveness of Sampling Strategies

The four final matrix sampling strategy/industry source combinations were examined to estimate their cost-effectiveness. The basic procedure was:

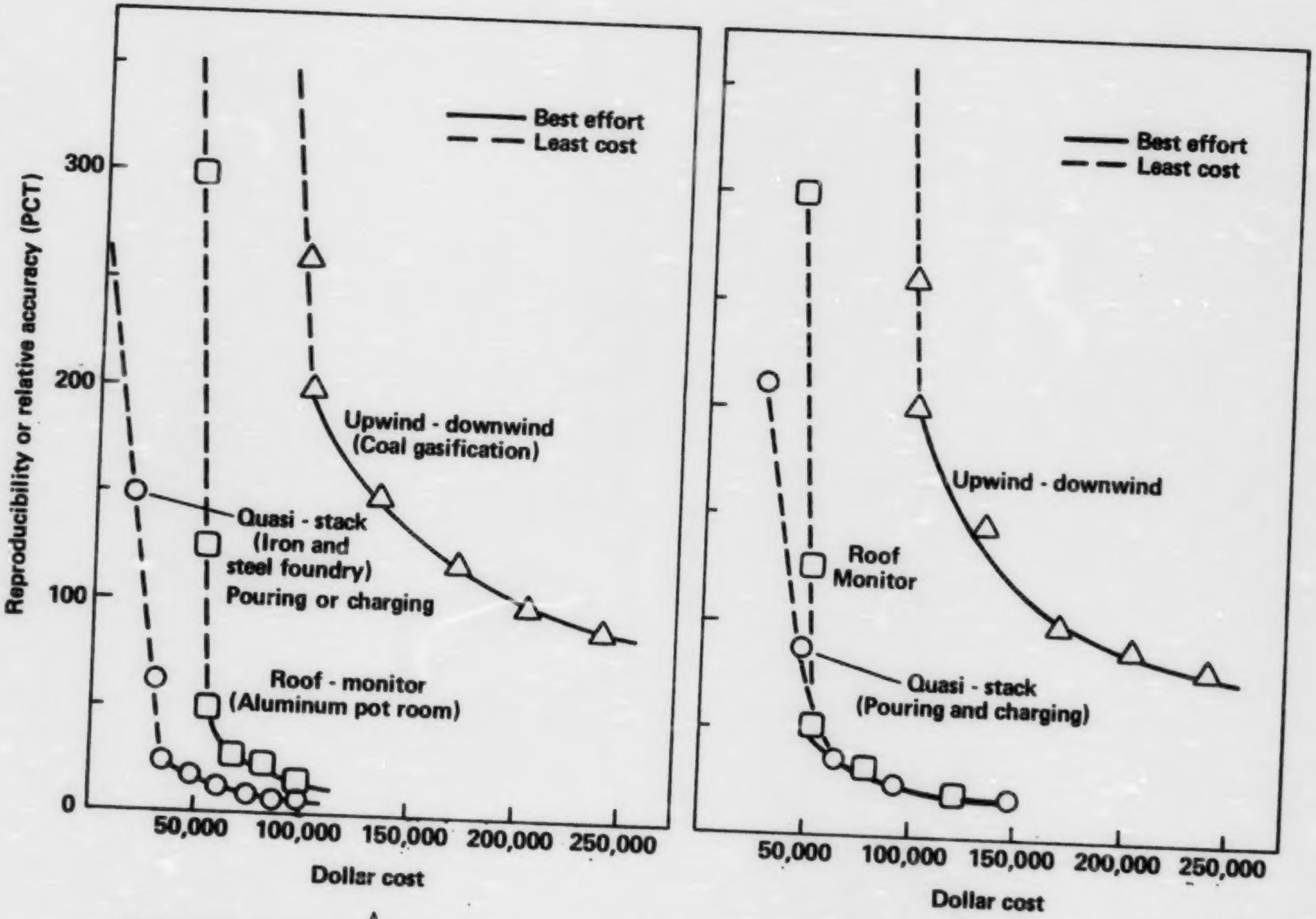
1. Determine accuracy and reproducibility of the techniques.
2. Determine minimum experiments required to achieve the above.
3. Compare the four techniques under the best conditions for which they can be employed.
4. Establish matrix of strategy, industry in which employed, fugitive emissions measured, costs, accuracy, and reproducibility.
5. Develop cost curves for each strategy and plot against the relative error limits (error limit depends on the number of experiments run).

Figure 5-2a shows such a cost curve. It was developed from the basic costs of experiments plotted against the relative error. It was assumed that the two quasi-stack sampling strategies were equivalent in costs.

This procedure results in relative cost-effectiveness curves for different sources of fugitive emissions, whereas to compare each of the strategies to each other, either a weighting factor for the importance of the fugitive emissions measured needs to be applied, or another procedure must be used to determine the cost-effectiveness for the same fugitive emission source.

The following alternate procedure for evaluating all strategies on the same basis was used:

1. Determine accuracy and reproducibility of the techniques.
2. Determine minimum experiments required to achieve this.



A

Cost-effectiveness of four fugitive emission source sampling strategies applied to different sources.

B

Cost-effectiveness of four fugitive emission source sampling strategies applied to the same source. (2 converters in one copper smelter building).

Figure 5-2

3. Compare results of use of all four strategies in same industry or process (e.g., copper smelter converter house).
4. Determine cost vs. accuracy and reproducibility for each.
5. Plot cost vs. reproducibility for each strategy (Figure 5-2b) by varying the number of experiments and thereby changing the relative error limits of tests and the costs.

This alternative procedure clearly shows that the cost-effectiveness of a fugitive emission source sampling strategy is dependent on the source to be tested. It can, for instance, be shown that a quasi-stack strategy is most cost effective when a single source such as iron cupola charging is studied, whereas in a copper smelter converter building (multiple enclosed sources) a roof monitor strategy might be preferred. In a coal gasification plant, the upwind-downwind strategy would probably be the choice.

5.3 Task III - Prepare a Technical Manual for the Measurement of Fugitive Emissions

A draft of a field test procedure for mold pouring in an iron foundry was prepared.

5.4 Task IV - Field Test of a Fugitive Emission Technical Manual

Task IV consisted of the field evaluation of a procedure for the quasi-stack sampling method for industrial fugitive emissions, which was developed during Task III of the program. The procedures document presents general guidelines for the design and conduct of a field test program utilizing the quasi-stack method. The field evaluation was intended to gather relevant information for refinement of the procedures document based on actual field operating experience.

As a result of an extensive literature study executed during Tasks I and II which dealt with the identification of sources of fugitive emissions and the evaluation of sampling strategies, and further review by TRC and EPA, it was decided to evaluate the quasi-stack sampling method on fugitive emissions. As an example which was considered feasible, mold pouring in an iron foundry was chosen for the field study. Five foundries which were cooperative with TRC upon initial contact were inspected for suitability for these tests. A foundry located in southern Connecticut was selected.

This foundry operates one cupola furnace which has a melting rate of about 12 tons (109 kgs) per hour. Most of the production occurs in a large main bay area, where molds are assembled in place and remain stationary during pouring and cooling. Most of these molds contain sand cores. An overhead crane is used to transport the pouring ladle around the bay and to deliver the molds to the sand shakeout operation.

It was possible for the field test setup to be located at one end of the main bay where it was isolated from much of the foundry activity. Operation of the cupola, manufacture of the sand cores, mold shakeout, product cleaning, and a large part of the mold assembly activity occurred either at the other end of the bay or in another part of the foundry. A ventilation system was designed and installed to capture emissions during the initial pouring of hot metal in the mold and the subsequent cooling period. The system consisted of an enclosure or hood for a test mold, a fan, and associated ductwork.

Pollutant emission measurements were made in ports located in a straight run of the ductwork. The following listing summarizes the specific equipment employed in the test program along with the types of pollutants measured:

1. IKOR Model 206 Continuous Particulate Monitor: dry filterable particulate.
2. EPA Method 5 Particulate Train per Federal Register, August 17, 1971: dry filterable particulate, organic and inorganic condensibles particle size, and particulate composition (i.e., iron, silica, nitrate, and sulfate).
3. Glass Innovation (G.I.) Cascade Impactor with EPA Method 5 condensible train: dry filterable particulate, organic and inorganic condensibles, and particle size distribution (aerodynamic diameter).
4. Beckman Model 109 Flame Ionization Detector: total hydrocarbons (methane basis).
5. Intertech Model Infra-2 Non-dispersive Infra-red Analyzer: carbon monoxide.

A trailer was located on the foundry bay next to the test setup. This trailer served as an instrument and chemical field laboratory (reference Figure 5-3). In addition, high volume air sampling stations were used to measure ambient air particulate concentrations in the foundry main bay.

The test program for Task IV was conducted during the period from March 7 to March 21, 1975. Twenty-three (23) individual mold pouring tests were run as well as four background tests. While a wide variety of mold types were encountered, the mix was considered representative of a normal production schedule for this foundry.

This report presents the results of the measurements and discusses their significance, both with respect to the foundry operation and the quasi-stack measurement method employed. The measurement and analysis procedures are also presented in detail.

The purpose of the field test program was to evaluate the quasi-

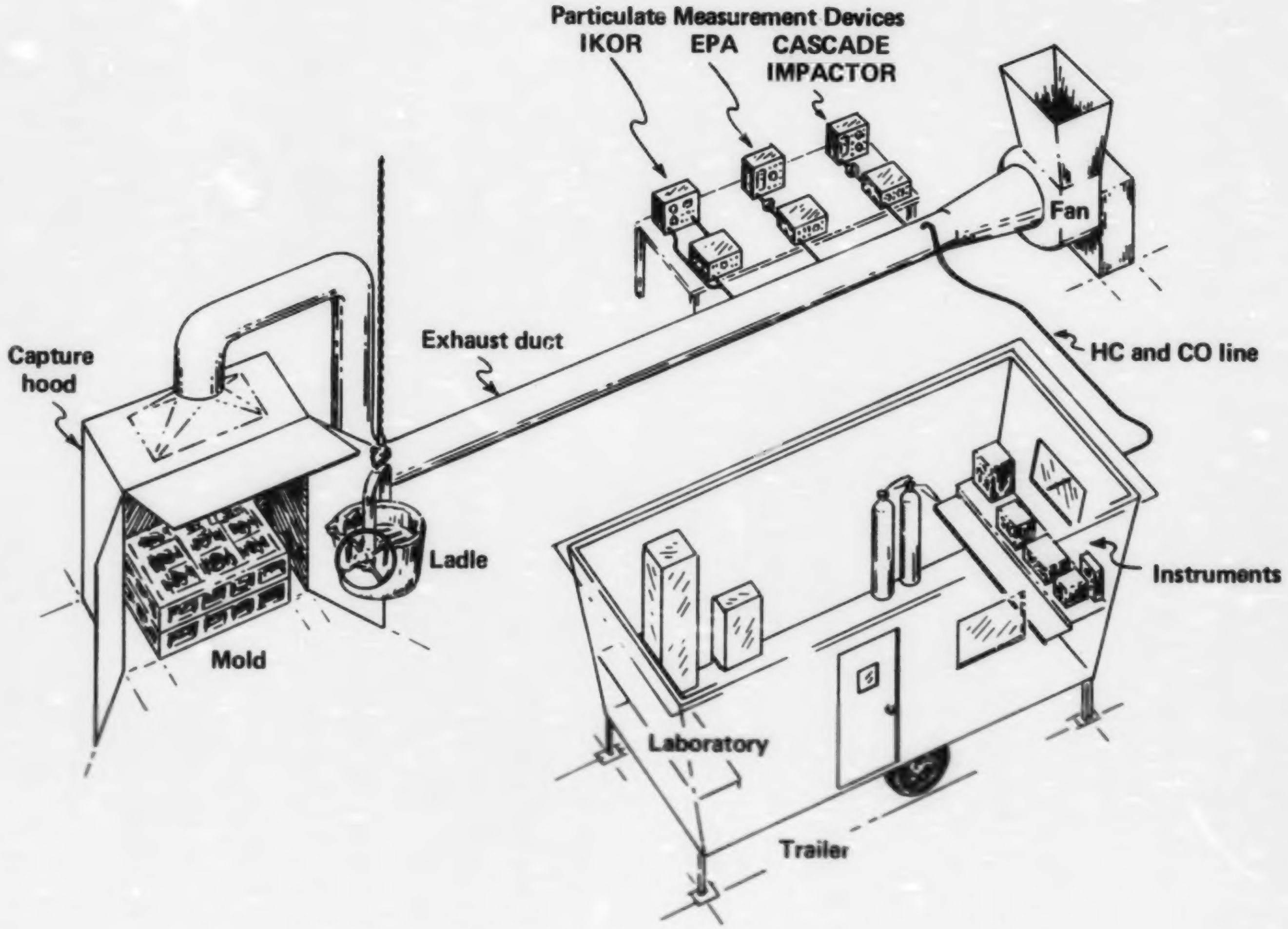

Particulate Measurement Devices
IKOR
EPA
CASCADE IMPACTOR
Fan
Capture hood
Exhaust duct
HC and CO line
Ladle
Instruments
Mold
Laboratory
Trailer

Figure 5-3: Illustration of test set-up for measuring fugitive emissions from mold pouring in a gray iron foundry. (EPA Contract 68-02-1815)

stack sampling strategy for measuring fugitive emissions (in this case, mold pouring in an iron foundry) and to provide field experience for improving the strategy's test procedures. Emission concentrations were obtained during the evaluation and they were related to the process conditions at the time of the test.

Table 5-8 presents a summary listing of the tests that were conducted, the associated casting/core weights of the molds that were poured, and the test methods that were used to measure the mold pouring emissions. Table 5-9 summarizes foundry activity during tests.

5.4.1 Summary of Procedures and Analysis

5.4.1.1 Description of the Mold Pouring Hood Arrangement (Refer to Figure 5-3)

A hood was designed to enclose a single mold and capture most of the emissions given off from the mold and ladle during the initial pour and after the pour while the mold was cooling. After witnessing several mold pouring operations on preliminary inspections, it was observed that there was a significant evolution of hot exhaust gas from the ladle alone. The enclosure design, therefore, had to take into account both the ladle and mold configurations. Guidelines established by the American Conference of Governmental Industrial Hygienists were used to develop initial plans. Modifications to the design were made to incorporate features dictated by specific plant operating practices. Since mold and ladle transfer to and from the hood would be by overhead crane, it was necessary to provide hinged side and top panels for better access. This also provided a greater degree of operator safety while handling the ladle during the pour. The final hood design, there-

TABLE 5-8

SUMMARY OF TESTS - MOLD POURING

Test No.	Test Date	Process Conditions		Test Methods						Process Conditions	
				Particulate							
		Casting Wt., LBS.	Core Wt., LBS.	EPA Method 5	Cascade Impactor	Continuous Monitor	Other	Total HC (CH_4 Basis)	CO	Casting (kgs)	Core (kgs)
1	4/7/75	300	250	✓	✓			✓	✓	363	114
2	4/7	300	275	✓	✓		Hi-Vol[1]	✓	✓	136	125
3	4/7	1000	900	✓	✓	✓		✓	✓	454	408
4	4/8	600	500	✓	✓	✓		✓	✓	272	227
5	4/8	600	500	✓	✓	✓	Ditto	✓	✓	272	227
6	4/8	300	150	✓	✓	✓		✓	✓	136	68
B1	4/9	(Background Test-A.M.)				✓		✓	✓		
7	4/9	600	500	✓	✓	✓	Ditto	✓	✓	272	227
B2	4/9	(Background Test-P.M.)		✓		✓		✓	✓		
8	4/10	600	500	✓		✓		✓	✓	272	227
9	4/10	600	500	✓		✓	Ditto	✓	✓	272	227
10	4/10	600	500	✓		✓		✓	✓	272	227
11	4/14	300	150	✓		✓		✓	✓	136	68
12	4/14	300	50	✓		✓	Ditto	✓	✓	136	23
13	4/14	650	0	✓		✓		✓	✓	295	0
14	4/15	600	500	✓	✓	✓		✓	✓	272	227
15	4/15	300	125	✓	✓	✓	Ditto	✓	✓	136	56
16	4/16	300	175	✓	✓	✓	-	✓	✓	136	80
17	4/16	250	25	✓	✓	✓	-	✓	✓	114	11
B3	4/17	(Background Test-A.M.)		✓		✓		✓	✓		
18	4/17	250	30	✓	✓	✓		✓	✓	114	14
19	4/17	250	30	✓	✓	✓	Hi-Vol[1]	✓	✓	114	14
20	4/17	250	30	✓	✓	✓		✓	✓	114	14
B4	4/21	(Background Test-A.M.)		✓				✓	✓		
21	4/21	600	300	✓	✓	✓		✓	✓	272	136
22	4/21	250	125	✓	✓	✓	Ditto	✓	✓	114	56
23	4/21	250	125	✓	✓	✓		✓	✓	114	56

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[1] Background tests run by Hi-Volume Sampler near test booth and in production area.

TABLE 5-9

FOUNDRY ACTIVITY DURING TESTING

Test No.	Test Date	Test Start Time	Description of Foundry Activity During Testing
1	4/7/75	11:58	
2,3	4/7/75	1:12,2:18	~ 15 molds brought into booth area during tests.
4	4/8/75	12:07	Pouring and positioning molds near booth during test.
5	4/8/75	1:29	Positioning molds near booth, no pouring.
6	4/8/75	2:49	Mold from test #5 dropped 10 ft in front of booth upon removal; sat smoking during test #6, caught somewhat by draft of booth.
B1	4/9/75	10:25	Booth background: no mold in booth, no production or molds at trailer end of main bay. Activity at Herman press.
7	4/9/75	12:06	Molds transferred and assembled in bay area in front of booth during last half of test.
B2	4/9/75	2:11	Pouring completed ~ 2:30. 16 molds poured near booth.
8	4/10/75	12:05	Mold pouring on bay in front of booth 12:10-12:20.
9	4/10/75	12:49	Mold pouring on bay cupola - Herman.
10	4/10/75	1:45	Flask transfer to Herman during run.
11	4/14/75	11:57	Pouring of molds near cupola during test. Operators and mold assemblers at lunch during test period - emissions from mold alone. Booth top in full raised position during pour.
12	4/14/75	1:05	Mold assembly in front of booth during test. Both roof ventilators over booth on during test. Pouring at other end of bay.
13	4/14/75	2:01	Pouring molds in front of booth 2:00-2:10. No other activity. Ventilators on, room clear.
14	4/15/75	11:59	Pouring on main bay from Herman to cupola, 12:00-1:00. No mold pouring near booth 12:00-1:00. Roof fans closed during first 15 minutes of test, then opened. Mold assembly in front of booth 12:35-1:00.
15	4/15/75	1:25	Ventilators on over booth. Flasks next to booth being transferred to Herman 1:20-1:45. Mold assembly in front of booth 1:20-1:50.
16	4/16/75	12:08	Roof monitors on, mold assembler on break 12:00-12:30. Pouring on main bay cupola to Herman 12:10-12:30, 12:30-1:00.
17	4/16/75	2:06	Molds in front of booth poured. No assembly occurring. Roof fans on.
B3	4/17/75	10:08	Mold preparation between Herman and cupola. Preparation near booth at 10:30. Roof fan on during last 15 minutes of test.
18	4/17/75	12:44	Roof monitors on. Mold assembly near booth during test. Pouring at cupola end of bay 12:30-1:40. Molds in front of Herman poured 1/2 hour before test. Room very hazy ~ 1:15. 1:20 - cleaning Herman with air gun.
19	4/17/75	1:49	Mold pouring near booth started near end of test. Roof vents on. No activity in this end of bay 1:45-2:15. Pouring at other end of bay 1:45-. Molds from this afternoon still smoking near booth.
20	4/17/75	2:37	Mold pouring in front of booth fron end of Test 19, continuing until 2:45. Molds noticeably smoking during latter part of test (on bay floor).
B4	4/21/75	12:12	Mold assembly between cupola and Herman. Flask transfer to Herman. Core cleaning with air hose in front of booth ~ 10:25.
21	4/21/75	12:05	Roof vents on. Mold assembly break. Mold pouring in front of Herman and booth 12:05-12:25. Pouring at other end of bay, 12:25-test end.
22	4/21/75	1:09	Roof vents on. Mold assembly in front of booth. One row of molds smoking from pour 12:05-12:25. Flask transfer to Herman next to booth during test.
23	4/21/75	2:10	Atmosphere very hazy. 2:10 mold blowout next to trailer. Mold pouring of second rwo in front of booth 2:10-.

fore, was functional from the standpoint of plant operating practices, provided ventilation characteristics sufficient to capture the mold pouring emissions, and incorporated physical dimensions dictated by the sizes and configurations of the mold and ladle.

A two-foot (0.65 meter) diameter duct served as the exhaust ductwork for the hood and as the sampling test section. This duct discharged from the top of the hood and, by the use of three 90° elbows, was arranged to run horizontally, three feet above the floor. The horizontal section which incorporated a continuous run of about 22 feet (7 meters), contained the sample ports and test equipment probes.

The front opening of the hood was designed for a face velocity of 150 feet (46 meters) per minute (fpm). This ensured capture of most of the exhaust gases from mold pouring, particularly from the ladle when in the pour position. Based on an open face area of 57 square feet (5.4 square meters) for the hood and a design capture velocity of 150 fpm (46 meters/minute), the required exhaust volume flow is 8500 cubic feet (240 cubic meters) per minute (cfm). This exhaust flow in the two-foot (0.65 meter) diamter duct represents a velocity of 2500-3000 fpm (770 925 meters/minute) which is considered adequate to insure that deposition of particulate by settling will not occur in the duct. The fan for this system was located at the end of the horizontal duct run. The exhaust flow was returned directly to the bay. This was considered necessary to prevent the hood enclosure from causing room air changeover and thereby affecting the background concentrations of contaminants which may have resulted if discharge was to the outside of the foundry structure. (The location of this hood in the foundry and the quantity of air moved would have made this system one of the largest exhaust systems in the bay area.) Figure 5-3 schematically depicts the mold pouring hood arrangement, including associated ductwork, sample equipment locations, and field laboratory trailer. More detailed descriptions of the trailer and sampling equipment are presented in other sections.

5.4.1.2 Description of Sample Port Locations

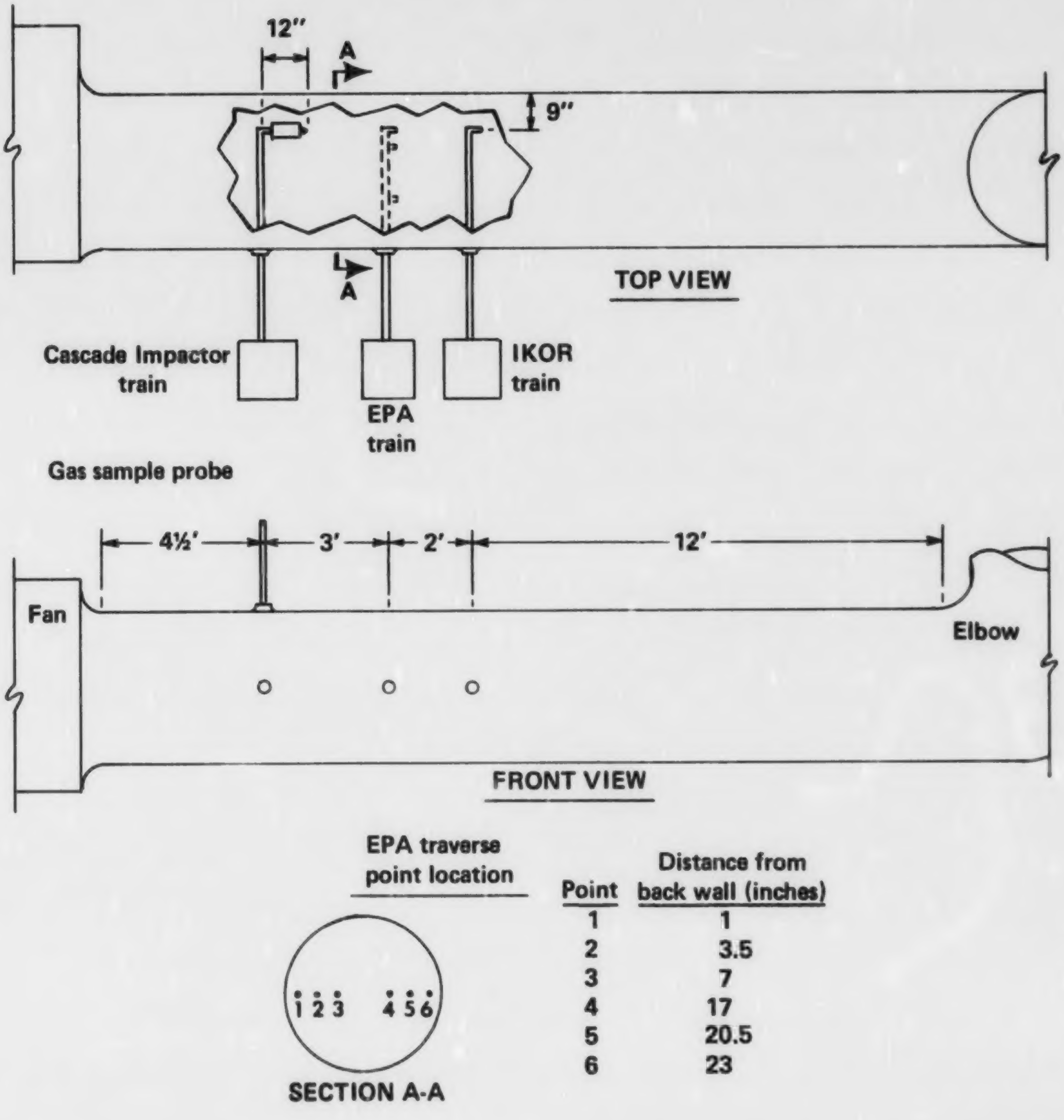
The location of four sample test ports in the horizontal duct is shown in Figure 5-4. Pertinent dimensions and the arrangement of the sample equipment are also depicted in this figure.

The placement of the three side ports was chosen to minimize turbulence effects. Disturbances to the normal flow pattern were expected on the downstream side of each probe; therefore the actual port locations had to be arranged so that any one probe was not in the turbulent wake of the preceding probe.

The IKOR continuous particulate monitor probe was located in the furthest upstream port. This probe was positioned at a point nine inches (23 cm) from the far side, which was determined from a velocity traverse to represent a point of average velocity. The IKOR probe was not traversed during the test program.

The probe for an EPA Method 5 particulate train including a condensible collection section was located in the middle port. A six point horizontal traverse was conducted for each test. Figure 5-4 gives the position of the traverse points with respect to the duct diameter.

A Glass Innovation (G.I.) Cascade Impactor System coupled to a


12"
A
9"
A
TOP VIEW
Cascade Impactor train
EPA train
IKOR train
Gas sample probe
4½'
3'
2'
12'
Fan
Elbow
FRONT VIEW
EPA traverse point location
1 2 3 4 5 6
SECTION A-A

Point	Distance from back wall (inches)
1	1
2	3.5
3	7
4	17
5	20.5
6	23

Figure 5-4: Schematic Diagram of Sample Port Locations

condensible train identical to the EPA Method 5 train was located in the third port. As in the case of the IKOR, the impactor probe was positioned at a point nine inches (23 cm) from the rear wall and was not traversed during the tests. Although downstream of other particulate measurement devices, no significant effect on the mass emissions as measured by the impactor was seen from its placement in the wake of other instrument probes.

A gas sampling probe was placed in the vertical port situated at the same location as the G.I. cascade impactor and inserted a distance of about nine inches (23 cm). Twenty-five feet (7.7 meters) of tygon sample line carried a sample flow from this probe to a fan-manifold system contained in the laboratory trailer. This gas flow provided gas samples for the Beckman hydrocarbon analyzer and the Intertech carbon monoxide analyzer which were operated in the trailer.

The placement of the three sampling train probes and the one gaseous sampling probe in the same duct section was designed so that all equipment could be operated simultaneously during each test. This allowed for comparisons among sampling techniques.

5.4.1.3 Field-operated Instrument and Chemical Laboratory

A utility trailer was located inside the foundry close to the hood ducting near the fan discharge. It was employed to provide a clean environment within the foundry for sample preparation and recovery and for the operation of the hydrocarbon and carbon monoxide instrumentation and chart recorders.

A manifold system consisting of two-inch (5 cm) diameter glass piping and an exhaust blower was used to collect the gaseous sample from the vertical sampling probe and tygon tubing. This sytem exhausted excess flow out of the trailer through flexible ducting on the blower discharge, while the hydrocarbon and carbon monoxide analyzers extracted independent samples on a continuous basis from the glass piping. Each instrument extracted a small portion of the total sample flow and only as much as it needed for analysis.

A strip chart recorder with a three channel output was set up in the trailer to present continuous traces for the hydrocarbon analyzer, carbon monoxide analyzer, and for the IKOR continuous particulate monitor. Although the IKOR output was continuously monitored on the strip chart recorder in the trailer, the instrument itself was operated at the test port location, as mentioned previously.

The trailer, in addition to serving as an instrument laboratory, was important in functioning as a field chemical laboratory. Having the availability of a relatively clean environment located close to the test setup increased assurance that the integrity of the samples would be maintained. A procedure was adopted and followed (discussed in more detail in Section 5.4.2) for handling samples in the field. All sample mediums, i.e., filters, were handled and assembled in the trailer prior to each test. At the end of each test all collected samples were again handled and recovered inside the trailer. Samples were placed in suitable containers and logged properly. Some sample preparation steps were done in the laboratory trailer that would normally have been done at TRC's permanent facilities. Filters were stored in a dessicator after removal from their holders and chemical extractions of the liquid medium in the condensible trains were performed, yielding separate organic and inorganic fractions. These steps aided in shortening the overall turnaround time for sample analysis and thereby permitting the test team to evaluate data at least on a preliminary basis within only a few days. This procedure would indicate or suggest the need for modification to planned procedures as the program progressed.

At the end of each test day, all samples were assembled in the trailer, prepared for transport to TRC's Wethersfield, Connecticut, permanent laboratory, and logged. As will be discussed later, samples were delivered to the office laboratory on the day of their respective tests and were immediately prepared for subsequent analysis.

5.4.1.4 EPA Method 5 Particulate and Condensible Train

Particulate sampling was accomplished by means of the EPA collection train, Method 5, as described in the August 17, 1971, edition of the Federal Register. This method permits the measurement of both dry filterable particulate and condensible particulate material. It is shown schematically in Figure 5-5 and consists of a nozzle, glass-lined probe, filter, four impingers, vacuum pump, dry gas meter, and an orifice flow meter. Following the probe, the gas stream impacts directly on a 2-1/2 inch Millipore membrane filter supported on a coarse fritter-glass disc in a glass filter holder. A membrane type filter was used to permit microscopic particle size analysis and particulate composition determinations to be performed. An ice bath containing four impingers was attached to the back end of the filter via a short section of glass connectors. All condensible material in the sample stream was collected here. The stack velocity pressure was measured using a calibrated type-S pitot tube and inclined manometer, while the stack temperature was monitored by a thermocouple-potentiometer arrangement. A nom-

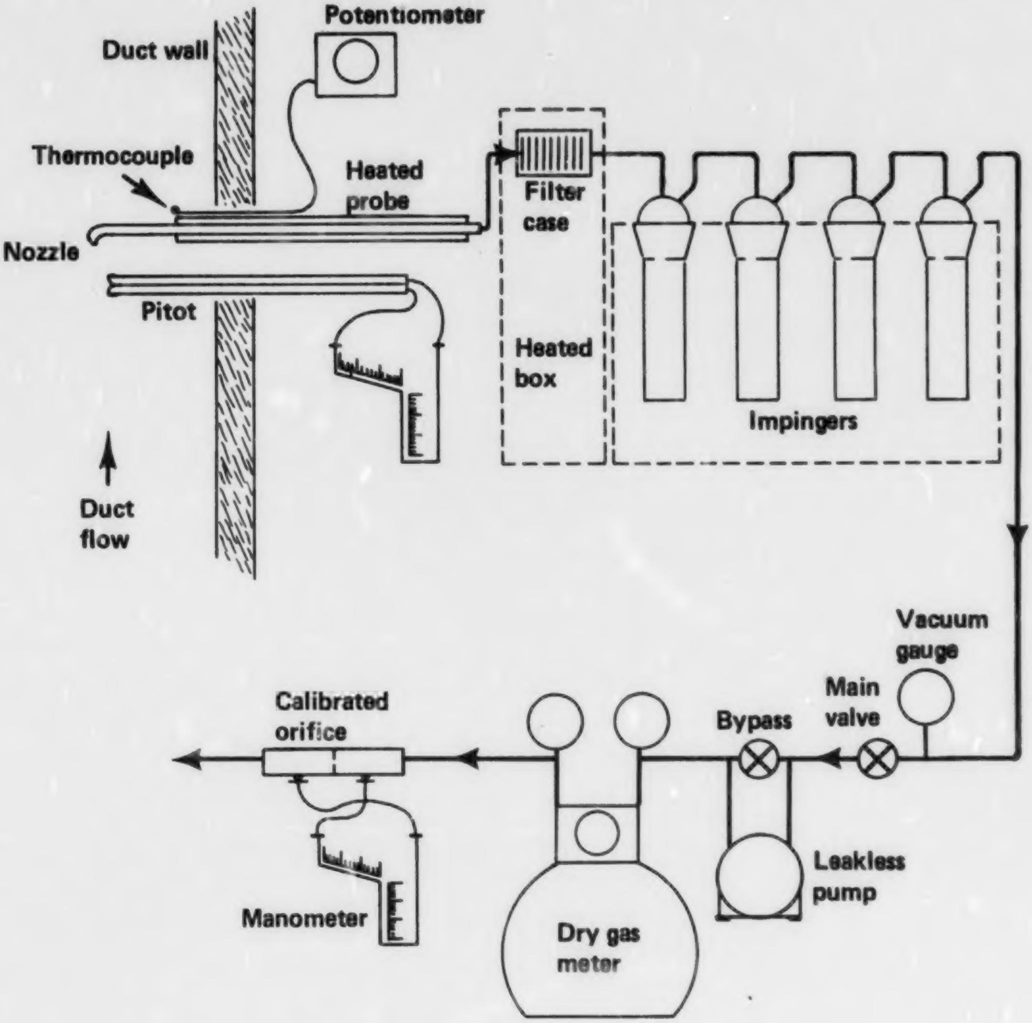

Potentiometer
Duct wall
Thermocouple
Heated probe
Filter case
Nozzle
Pitot
Heated box
Impingers
Duct flow
Vacuum gauge
Main valve
Bypass
Calibrated orifice
Leakless pump
Manometer
Dry gas meter

Figure 5-5: EPA Method 5 Particulate Sampling Train Including Condensibles

ograph rapidly determined the orifice pressure drop which is representative of the sampling flow rate required for any pitot velocity pressure in order to maintain isokinetic sampling conditions. It is believed that particle pick-up would be weight-biased when either sub or super-isokinetic sampling rates are employed. Generally, a range of within ± 10 percent of isokinetic was an acceptable test. Sampling flow was adjusted by means of the needle valve and bypass valve arrangement on the leakless pump.

Test data recorded included test time, sample point location, sample duration at each traverse point, velocity pitot pressure, stack temperature and pressure, meter volume and temperature, and orifice pressure drop (see Appendix F for an example data sheet).

At the end of each test, the probe, filter, and impinger assembly were disconnected and transferred intact to the field laboratory. Samples were recovered and placed in the following containers:

<ins>Container #1 (plastic petri dish</ins>) - 2-1/2" (6.3 cm) membrane filter from glass holder.

<ins>Container #2 (glass jar</ins>) - acetone washings of probe and front half of filter holder.

<ins>Container #3 (glass jar</ins>) - total impinger solution (after volume recorded) and water wash of impinger.

<ins>Container #4 (plastic bottle</ins>) - silica gel from the fourth impinger.

<ins>Container #5 (glass jar</ins>) - acetone prewash of the probe before start of next test.

A more detailed description of sample recovery, handling, and analysis is presented in Section 5.4.2. A computer program developed by TRC was used to calculate the duct emission levels of particulate material in grains per actual and standard cubic foot, and the duct volume flow. Reference is made to the Federal Register, August 17, 1971, for the formulas used in performing the required computations.

5.4.1.5 G.I. Cascade Impactor and Condensible Train for Particulates

A Glass Innovation Model 226 multi-stage cascade impactor was operated in its in-stack mode and attached directly to the front end of a standard EPA Method 5 condensible train with only slight modifications. A specially designed type-S pitot was used which allowed for a velocity pressure reading to be taken at the impactor nozzle location. Sampling was performed isokinetically and data was recorded in much the same manner as for the EPA Method 5 train with the noteable exception that the cascade train was not traversed during the course of the test. Appendix G presents an example data sheet for the cascade impactor.

The impactor unit, which is illustrated in Figure 5-6, consists of a cone-shaped nozzle and six impactor stages followed by a built-in backup filter stage. All parts are constructed of stainless steel. The unit is designed to hold seven radially slotted glass fiber filters and one glass fiber backup filter as follows:

Filter	Type	Location
1	Slotted	Top of Stage 0
2	Slotted	Top of Stage 1
3	Slotted	Top of Stage 2
4	Slotted	Top of Stage 3
5	Slotted	Top of Stage 4
6	Slotted	Top of Stage 5
7	Slotted	Bottom of Stage 5
8	Whole	On backup filter support

The use of an impactor with filters for particle collection on

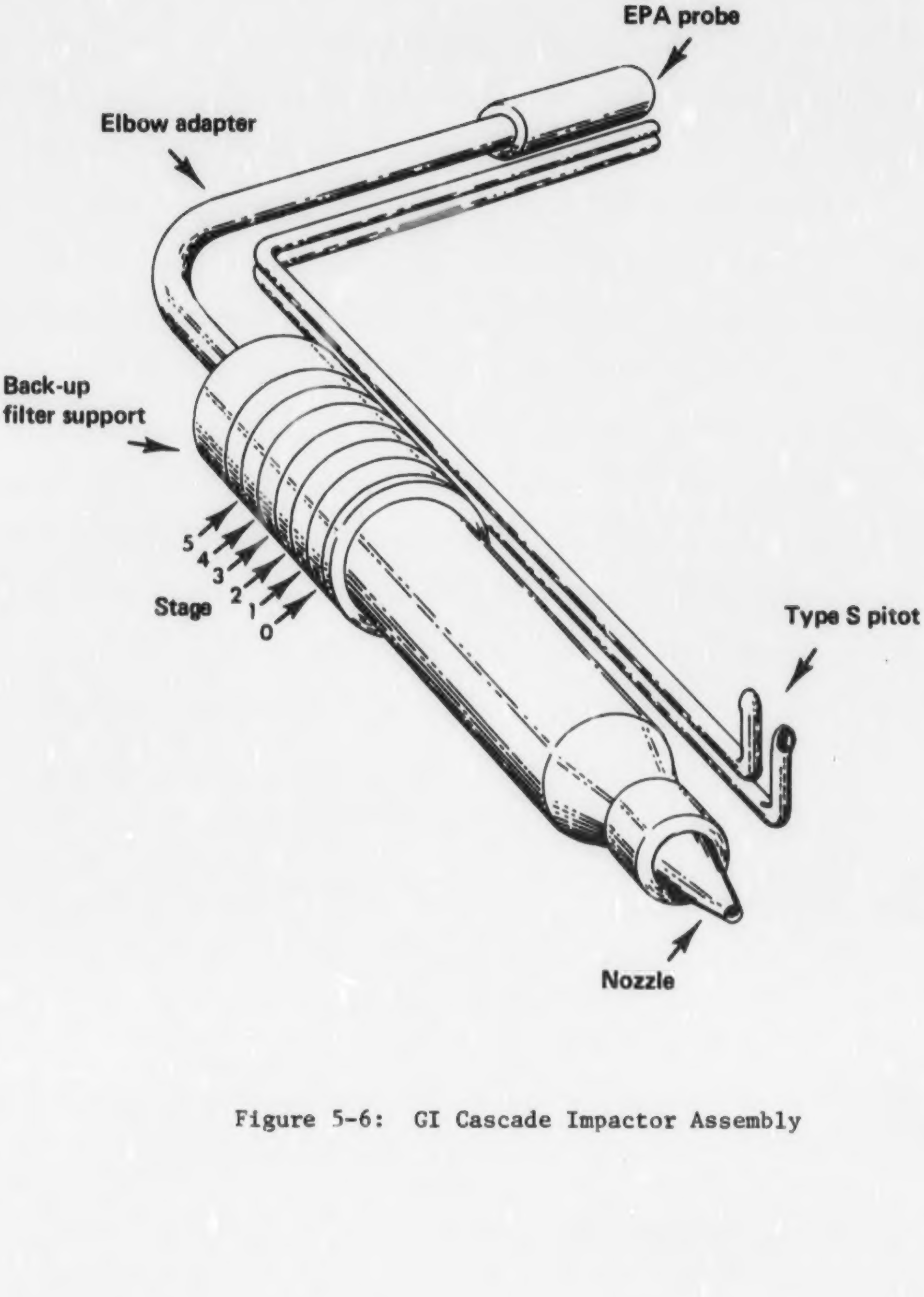

EPA probe
Elbow adapter
Back-up filter support
5
4
3
2
1
0
Stage
Type S pitot
Nozzle

Figure 5-6: GI Cascade Impactor Assembly

each stage was chosen since it offered a lower tare weight (as opposed to steel plate collection) and enhanced particle collection by minimizing reentrainment. The cascade impactor determines the aerodynamic particle size distribution with particle size cutoffs ranging from .5 to 15 microns. The actual cutoffs obtained depend on the operating conditions during a test as compared to the unit's calibration data. Since this impactor is designed to capture all particulates, it is also used to determine total filterable particulate emissions. As mentioned previously, this train contains a condensible section identical to the EPA Method 5 train so that condensible particulates are also measured.

At the end of each test the sampling train was partially disconnected with the impactor and impingers transferred intact to the field laboratory. Samples were assigned containers as follows:

Containers #1-8 (plastic petri dishes) - eight impactor stage filters from the cascade device.

Container #9 (glass jar) - total impinger solution (after volume recorded) and water wash of impingers.

Container #10 (plastic bottle) - silica gel from the fourth impinger.

Probe wash and prewash procedures were not followed on the cascade impactor train since the impactor (filter) was located at the front of the sampling ahead of the probe. Section 5.4.2 presents additional detail on the sample recovery, handling, and analysis procedures. The duct emission of particulate in terms of grains per actual and standard cubic foot was determined by TRC's computer program as discussed in Section 5.4.1.4. The aerodynamic particle size distribution was obtained by applying the weight percentage of material captured on each stage to the mean particle diameter representative of that stage.

5.4.1.6 IKOR Model 206 Continuous Particulate Monitor

An IKOR continuous particulate monitor, which was supplied by EPA's Industrial Environmental Research Laboratory, was used to provide a quantitative measurement and a real-time continuous display of mold pouring particulate emissions. The system, shown schematically in Figure 5-7, consists of a probe, sensing unit, gravimetric filter unit, and a control unit with signal integrator.

Particulate matter in the gas stream flowing through the probe collides with an inline sensing element resulting in a transfer of charge between the particle and sensor. An electrical signal is generated which is believed to be in response to the mass rate of particulate emissions when the characteristics of the particles do not vary with time. A calibration factor is obtained by developing a ratio between a simultaneous gravimetric sample collected in the filter unit (142 mm glass fiber filter) and an integrated signal of the instantaneous output response. This factor may then be used to convert subsequent integrated signals into mass particulate emissions.

Sampling is conducted isokinetically through the one inch I.D. probe. A specially designed venturi section along the probe length provides a means for measuring the sample flow rate. Isokinetic sampling conditions are attained by matching the pressure drops across the venturi and a type-S pitot monitoring the duct velocity. The sample flow is adjusted by a knob on the control unit which regulates a variable

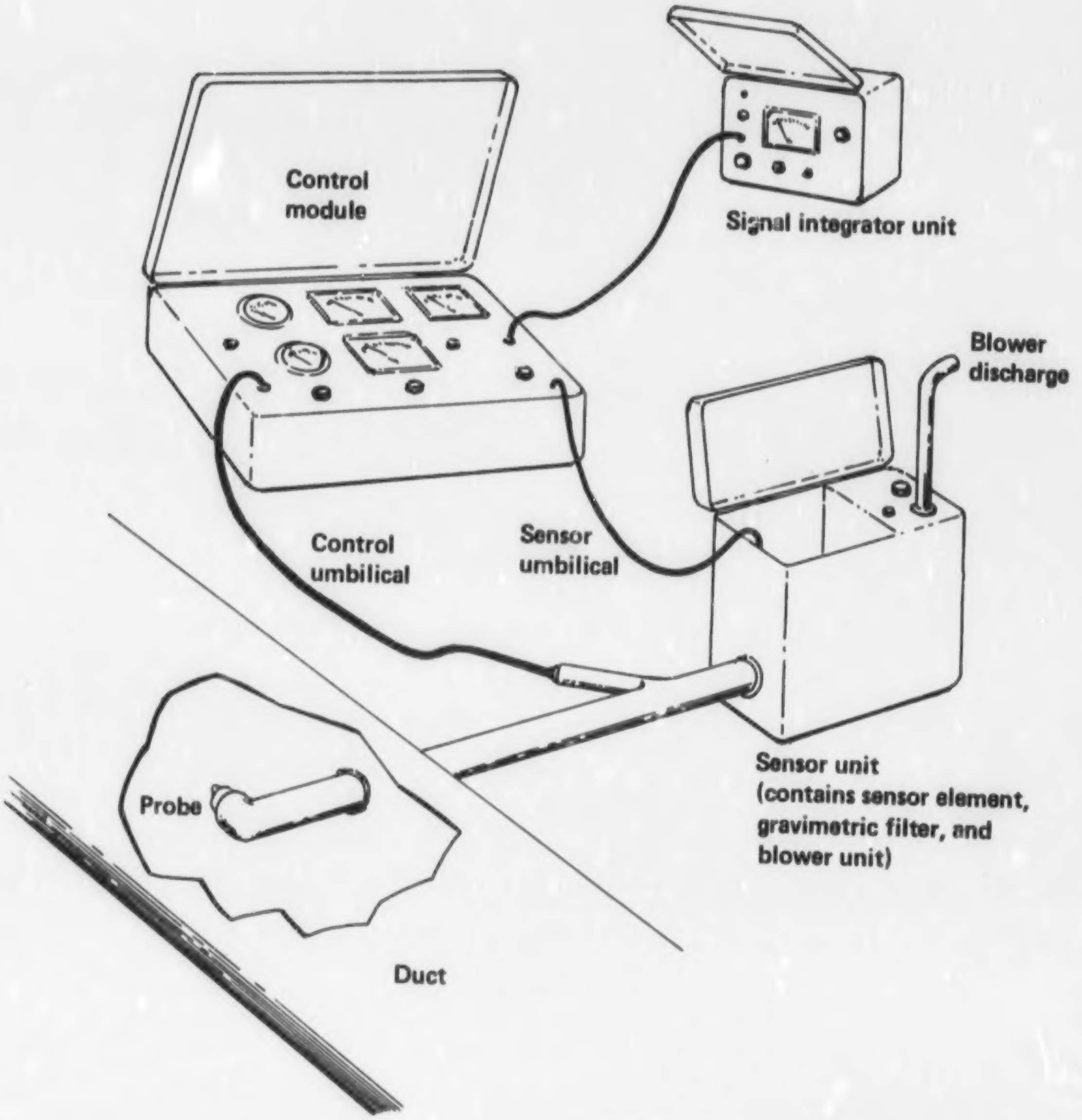

Control module
Signal integrator unit
Blower discharge
Control umbilical
Sensor umbilical
Sensor unit (contains sensor element, gravimetric filter, and blower unit)
Probe
Duct

Fig. 5–7 IKOR continuous particulate monitoring system.

speed blower located downstream of the sensor element and gravimetric filter unit.

Recorded data included the test time, sample velocity pressure, stack velocity pressure, stack temperature, sensor temperature, integrator parameters, and the integrated signal. An example data sheet can be found in Appendix H. For those tests which include a filter run (for calibration purposes), the filter cartridge was removed and transferred to the field laboratory. The recovered filter was placed in a plastic petri dish. Handling and analysis of the filter is discussed in Section 5.4.2. Duct particulate emission levels in terms of grains per actual and standard cubic foot were obtained by converting integrated signal data through application of the calibration factor.

5.4.1.7 Beckman Model 109 Flame Ionization Detector for Total Hydrocarbons

Figure 5-8 shows the setup of the hydrocarbon flame ionization detector which was located in the laboratory trailer. A continuous display of the output was provided by means of a chart recorder. The hydrocarbon analyzer abstracted a small portion of the total sample flow from the gas sampling manifold system. Calibration of the hydrocarbon analyzer was performed with a known concentration of methane gas in nitrogen. The data output is therefore presented in terms of the calibrating methane gas (as parts per million CH_4).

5.4.1.8 Intertech Model Infra-2 Non-dispersive Infrared Analyzer for Carbon Monoxide

The carbon monoxide analyzer is shown schematically in Figure 5-8. The measurement of carbon monoxide by non-dispersive infrared is the

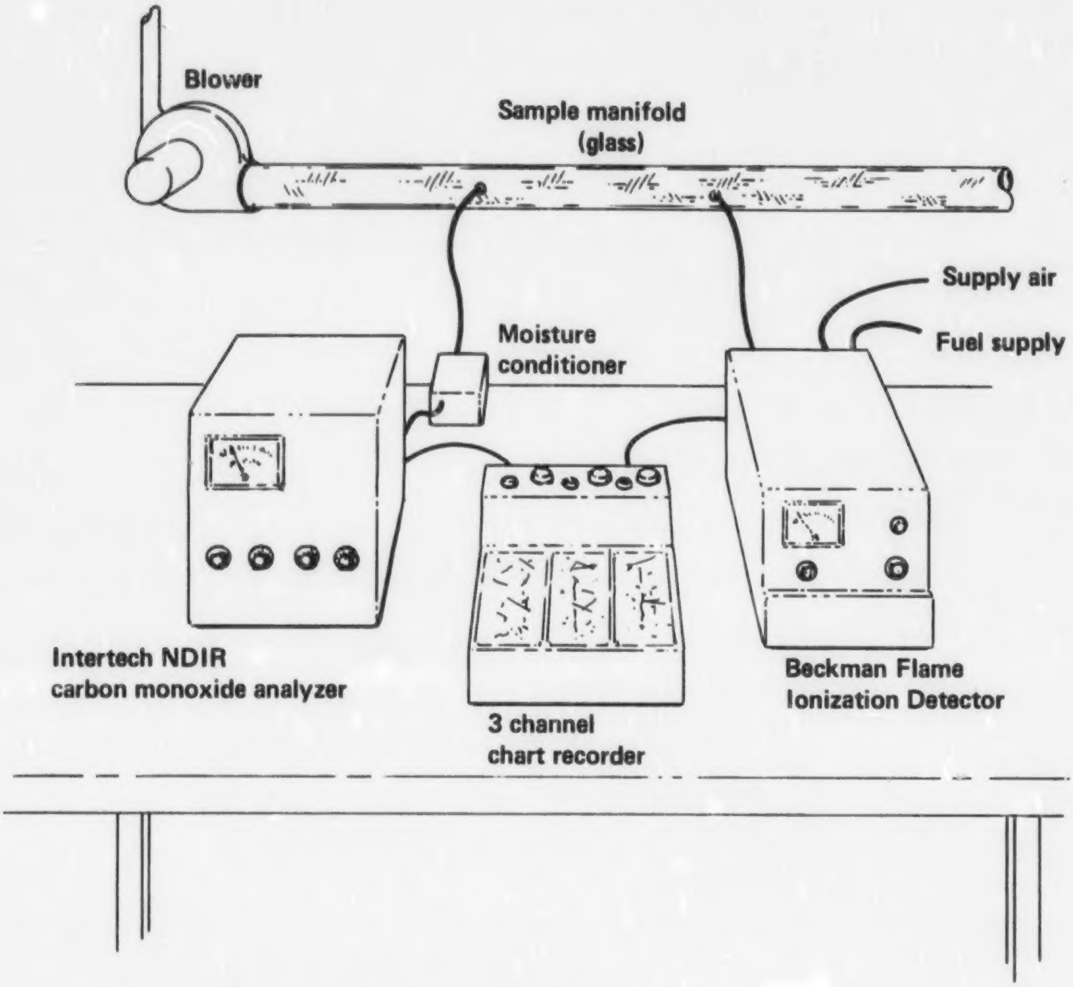

Blower
Sample manifold (glass)
Supply air
Fuel supply
Moisture conditioner
Intertech NDIR carbon monoxide analyzer
3 channel chart recorder
Beckman Flame Ionization Detector

Fig. 5-8 :Schematic diagram of laboratory trailer set-up showing hydrocarbon and carbon monoxide analyzers.

reference method acknowledged by EPA. Calibration of the carbon monoxide analyzer was made with a gas of a known carbon monoxide concentration. As in the case of the hydrocarbon analyzer, a sample was obtained continuously from a glass sampling manifold and the analyzer output is presented on a strip chart recorder.

5.4.1.9 High-volume Filter Sampler for Ambient Particulate

The measurement of ambient particulate concentrations at two locations on the foundry main bay was accomplished with high volume sampling stations as illustrated in Figure 5-9. One sampling location was near the booth enclosure while the other was in a production area at the opposite end of the bay, near the cupola.

A metal shelter encloses a filter-blower assembly in such a manner that a measurement of suspended particulates is obtained. A high volume blower with a flow range of 20 to 60 cubic feet (0.5-1.7 cubic meters) per minute draws sample into the shelter hood through slots at the top. Particulates are captured on an 8 inch by 10 inch (20.3 by 25.4 cm) glass fiber filter attached to the front of the blower.

Sample flow through the unit is monitored by a calibrated rotameter attached to the blower. Data collected during each test included sample time, duration of test and the initial and final sample flows. Appendix I contains a copy of a data sheet for the hi-vol ambient sampling procedure. Filters were removed from the shelter at the end of each test, folded, and placed in a manila envelope. Section 5.4.2 discusses the procedures for handling and analyzing the filter samples.

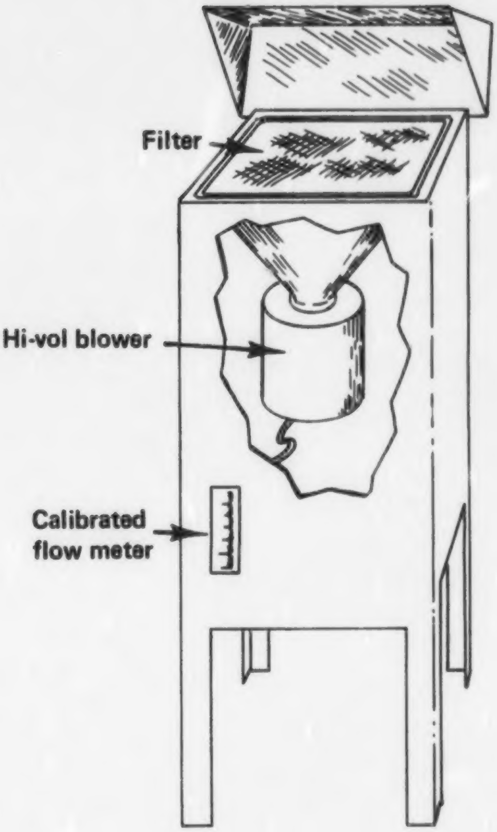

Filter
Hi-vol blower
Calibrated flow meter

Fig. 5-9: High volume sampling station for ambient particulates.

5.4.2 Analytical Procedures

A quality assurance procedure was developed which was primarily concerned with the proper methods for sample handling and analysis. A prescribed chain of custody was assigned for samples taken in the field and delivered to TRC's permanent laboratory facility in Wethersfield, Connecticut. The following sections describe all aspects of the quality assurance program including sample recovery and preparations in the field, transport of samples form the field to the permanent laboratory, analytical laboratory procedures, and data reporting.

5.4.2.1 Sample Recovery and Preparation in the Field

All sample media were handled in such a way that initial loading and final recovery were conducted inside the field trailer, except for the high-volume filters, which were loaded and recovered at the sampling site. A chemical technician operating inside the trailer was responsible for receiving the samples from the test team, for placing the recovered samples in assigned containers, for labeling and logging all samples, for conducting in-field analytical procedures, and for assembling samples in a suitable manner for transport to TRC's laboratory. It was considered essential that these activities be conducted in an enclosed structure such as the trailer. During the handling procedure, the test team remained outside the field laboratory, thereby minimizing undesirable interferences with the collected samples.

The filters from the EPA, cascade impactor, and IKOR trains were removed from their respective holders and placed in plastic petri dishes. The hi-vol filters were removed at the sampling station, folded, and transferred to a manila envelope. All filter samples were stored in a desiccator in the trailer during the day until preparations were made for transport to the permament laboratory. Desiccation in the field shortened the time required in the laboratory for the filters to achieve a constant weight.

Silica gel samples were removed from the fourth impinger of both the EPA and cascade trains and placed in their respective PVC plastic containers. The silica gel samples from each test were transferred to their original containers. All sample containers were tightly sealed and put aside until they were transported.

The liquid fraction from the first and second impingers of the condensible train (EPA and cascade) was handled as follows:

1. Total liquid volume was measured at the end of the test in a graduated cylinder. This volume was compared to the original 200 milliliters of distilled water placed in the impingers and the net gain in volume recorded on the field test data sheet.
2. The liquid was transferred to a glass sample container. Rinsings of the impingers and graduated cylinder with distilled water were added to the container.

Extractions were performed in the field on the liquid samples after recovery was complete. The samples were first extracted three times with 25 milliliters of chloroform and then three times with 25 milliliters of ethyl ether. The chloroform and ether layers were combined and transferred to a clean glass container. The container was then stored on ice. The remaining water layer from the extraction was transferred to another glass container and set aside until assembled for transport.

The EPA Method 5 probe was washed with acetone to rinse out any particulate matter adhering to the glass lining of the probe. One wash (labeled a pre-wash) was conducted before each test and recorded on the previous test's data sheet. A second probe wash was completed after each test. The probe wash samples were collected in glass containers and stored on ice.

Portions of the distilled water used in the condensible trains and the acetone for the probe washes were taken daily and transferred to glass containers. These samples served as blanks in the chemical analysis.

At the end of each test day all samples were gathered together by the chemical technician and prepared for transport to TRC permanent labatory facility. The filters were removed from the desiccator and sealed in the plastic petri dishes. Sample containers from the acetone probe washings and chloroform-ether extractions were placed in an ice chest. A log was prepared which identified the batch of samples being transported. An example of this log appears in Appendix J. Samples were delivered to the permanent laboratory by a member of the test team on the day of their respective tests.

5.4.2.2 Analytical Laboratory Procedures

Immediately upon delivery to the analytical laboratory the samples were unpacked and prepared by the test team technician for subsequent analysis. The lids from the petri dishes were removed and the filters (in the bottom half of the petri dish) were placed in a desiccator. The high-volume filters were placed on trays in the desiccator after being removed from the manila envelopes. Sample probe washes and condensible extractions were transferred from their respective glass containers to tared dishes. These dishes were placed in an evaporator hood to promote drying. The beaker containing the condensible water layer was placed on top of a hot plate (temperature ≃ 100°F [38°C] to induce evaporation and shorten the drying time. A log was maintained to identify samples for the analytical chemist performing the sample analysis.

The following is an outline of the procedures used by the analytical laboratory:

> Filter weight gain - filters were weighed on an analytical balance twice a day and until a constant weight was attained. Weights were reported to the nearest .01 milligrams.
>
> Silica gel weight gain - silica gel was removed from the plastic container and weighed on an analytical balance. The amount of moisture collected was represented by the difference between this value and an original silica gel weight of 200 grams. The results were reported to the nearest .5 grams.
>
> Particulate in probe wash - acetone was evaporated from the tared beaker until a completely dry residue remained. The weight gain of particulate in the probe wash, reported to the nearest .01 milligrams, was obtained from the difference in the final and tare weights of the beaker as measured on an analytical balance.
>
> Organic and inorganic condensible - the chloroform-ether and water extraction beakers were evaporated until a dry residue remained. The organic condensible particulate is represented by the residue from the chloroform-ether extraction while the inorganic condensible particulate is residue from the water layer. The results, obtained by a measured weight gain in the tared beakers, are reported to the nearest .01 milligrams for both organic and inorganic particulate.
>
> Microscopic particle sizing of EPA membrane filters - by assuming an even distribution of particulate on the membrane filter, a pie-shaped section was cut away. This piece was mounted on a viewing slide and made transparent by a mounting solution. Dark phase microscopy was used to count the particles. Results were reported in terms of the percentage of particulates by count in the ranges of <μ, 1-3μ, and >3μ.
>
> Iron content of particulate on EPA membrane filter - a portion of the membrane filter was dissolved in nitric acid to dissolve the

iron. The distribution of iron and total particulate was assumed the same for this portion as for the whole filter. The iron concentration of the known solution volume was determined by atomic absorption. The results were presented in terms of the percent iron content of the total particulate.

Quartz content of particulate on EPA membrane filter - nitric acid was used, as for iron, to dissolve a portion of the filter. Hydrochloric acid was added to eliminate any metallic interferences. Silicates are removed by a hot phosphoric acid digestion. The remaining quartz was dissolved with hydrofluoric acid. A color change produced when ammonium molybdate was added was compared with standards of known concentration on a spectrophotometer. Results were reported in terms of the percent quartz in the total particulate collected.

Nitrate and sulfate content of particulate on EPA membrane filter - A portion of the filter was refluxed for 90 minutes with water. The sulfate concentration of an aliquot was determined by the turbidimetric method. Treatment of the sample with barium chloride froms a barium sulfate suspension. The brucine method was used for nitrate determination. A yellow color change occurs when brucine reacts with nitrate while applying controlled heat. A spectrophotometer was used to relate the color change to a nitrate concentration as compared to standards.

After analysis was completed, all filters (except those destroyed in iron, quartz, sulfate, and nitrate determinations), extraction residues, and probe wash residues were assembled together and prepared for storage. Filters were returned to their respective petri dishes and sealed. Sample residues were redissolved in the original solvent (i.e., water acetone, chloroform-ether) and transferred to clean glass containers. The solvent was permitted to evaporate again leaving the sample residue. These containers were then sealed. Samples were assembled in a large box and assigned a storage area. These samples will be retained for possible future analyses until such time as their disposition is specified by EPA.

5.4.3 Evaluation of Particulate Concentration Data

The particulate concentration data obtained in the gray iron foundry tests were analyzed in detail. The low concentrations and the similarity of the results obtained using the three (EPA Method 5, Cascade Impactor, IKOR Continuous Monitor) different sampling methods made it imperative that a complete statistical analysis of the data be done to determine if there was:

A. Any significant difference between the results using the three sampling methods.

B. Any significant difference between these results for mold pouring fugitive emissions and background tests in the gray iron foundry.

The data comparison can be summarized as follows:

A. None of the three particulate sampling methods gave statistically significant difference in results when compared to inplant particulate background as measured by hi-vol filters.

B. The instantaneous particulate fugitive emissions can be inferred from the sample traces from the IKOR online continuous sampling. This is approximately an order of magnitude higher than the average over the entire test period and the general background concentration.

C. The period of high fugitive particulate concentration comes at the beginning of the test and is of short duration. This results in a low contribution of these actual fugitive emissions to the total particulate concentration over the test period (total = fugitive from pour + background).

D. Based upon C, it was considered that only gross estimates of fugitive particulate concentrations could be obtained from the data taken, since concentrations were low and near error limits of measurement.

E. Based upon the quasi-stack configuration used, only the IKOR continuous monitor was capable of sensing and measuring particulate fugitive emissions from the mold pouring operation. This could be accomplished without a filter on the IKOR after an emission factor has been established, or by accumulating on a single filter a large number of short interval mold pouring tests (run IKOR only during peak particulate periods) in the gray iron foundry and using the accumulated sample as an average result.

Table 5-10 presents the particulate concentration data obtained using the three comparative methods:

1. EPA Method 5, including condensibles.
2. Cascade Impactor, including condensibles.
3. IKOR continuous mass monitor.

The duct background test results are included in the table and ambient background data are presented from hi-vol tests that were conducted near the booth during mold pouring.

Mean values and standard deviations were calculated for all the tests which were within 90 to 110 percent of true isokinetic, including background tests. Table 5-11 summarizes these calculations. These results are for all isokinetic tests (all methods not necessarily run concurrently). The same calculation was repeated for isokinetic tests and background tests when all of the tests methods were run concurrently. Table 5-12 summarizes the latter calculation.

One aspect of reviewing the sampling strategy was to compare the various test procedures for accurately monitoring fugitive emissions. This was done statistically by conducting "t" and "f" tests on the mean values and standard deviations (Table 5-112) of the particulate results. The "t" tests are presented as a confidence interval for the true difference between the averages of the various test methods for both process emissions and background conditions. The "f" tests were conducted to confirm the results of the "t" tests. Intervals are reported for 95 or 99 percent confidence. If a 95 percent confidence interval is reported, no comment regarding a significant difference can be made with a confidence

TABLE 5-10

PARTICULATE CONCENTRATION DATA
GR/DSCF

Test No.	Test Dat	Process conditions		Test Method													IKOR Monitor: Filter	Hi-vol Filter (@ booth)
				EPA Method 5							Cascade Impactor							
		Casting Wt., lbs	Core wt., lbs	Total Part.	Condensibles			Probe Wash	Filter	% Iso-kinetic	Total Part.	Condensibles			Filter	% Iso-kinetic		
					Total	Inorg	Org					Total	Inorg	Org				
1	4/7/74	800	250	.020	.009	.003	.006	.006	.005	68	.003	.003	0	.003	0	102	--	.003
2	4/7	300	275	.014	.005	.001	.004	.004	.004	60	.006	.006	.001	.005	0	98	--	
3	4/7	1000	900	.011	.002	.001	.001	.004	.005	62	.005	.004	.001	.003	.001	102	.001	
4	4/8	600	500	.009	.006	.002	.004	.003	0	61	.012	.008	.003	.005	.004	67	.001	.001
5	4/8	600	500	.016	.004	0	.004	.009	.003	62	.004	.004	0	.004	0	58	.001	
6	4/8	300	150	.008	.007	.002	.005	.001	0	61	.010	.009	.005	.004	.001	67		
B1	4/9	(Background Test-a.m.)		--	--	--	--	--	--	--	--	--	--	--	--	--	.0006	.0001
7	4/9	600	500	.014	.007	.004	.003	.004	.003	58	.010	.010	.004	.006	0	33	.002	.0002
B2	4/9	(Background Test-p.m.)		.018	.013	.005	.008	.002	.003	61	--	--	--	--	--	--	.003	.0002
8	4/10	600	500	.006	.003	.001	.002	.003	0	101	--	--	--	--	--	--	.0007	.0021
9	4/10	600	500	.005	.004	.002	.002	0	0	99	--	--	--	--	--	--	.0015	
10	4/10	600	500	.006	.004	.002	.002	.001	0	98	--	--	--	--	--	--	.002	
11	4/14	300	150	.006	.004	.002	.002	0	.002	100	--	--	--	--	--	--	.0007	.0008
12	4/14	300	50	.017	.015	.012	.003	0	.002	101	--	--	--	--	--	--	.0012	
13	4/14	650	0	.005	.004	.002	.002	0	.001	102	--	--	--	--	--	--	.0013	
14	4/15	600	500	.007	.004	.002	.002	.002	.001	104	.002	.002	.001	.001	0	95	.003	.0024
15	4/15	300	125	.008	.007	.005	.002	.001	0	100	.003	.002	.001	.001	.001	97	.002	--
16	4/16	300	175	.008	.006	.004	.002	.001	.001	102	.003	.003	.002	.001	0	97	.002	--
17	4/16	250	25	.006	.004	.002	.002	0	.001	100	.003	.002	.001	.001	.001	103	.0023	--
B3	4/17	(Background Test-a.m.)		.008	.004	.002	.002	.002	.001	100	--	--	--	--	--	--	.0034	.0025
18	4/17	250	30	.008	.002	.001	.001	.005	.001	100	.001	.001	.001	0	0	98	.0033	
19	4/17	250	30	.005	.001	.001	0	.002	.002	103	.002	.002	.001	.001	0	106	.0012	
20	4/17	250	30	.002	.002	.002	0	0	0	104	.001	.001	.001	0	0	101	.0011	
B4	4/21	(Background Test-a.m.)		.007	.003	0	.003	.001	.003	99	--	--	--	--	--	--	--	.0035
21	4/21	600	300	.009	.005	0	.005	.003	.001	103	.004	.004	.002	.002	0	96	.0011	.0023
22	4/21	250	125	.003	.002	0	.002	.001	0	102	.007	.005	.002	.003	.001	99	.0023	
23	4/21	250	125	.008	.003	0	.003	.004	.001	103	.005	.003	0	.003	.002	99	.0035	

TABLE 5-11

SUMMARY OF STATISTICAL ANALYSIS

TOTAL OF ALL ISO-KINETIC TESTS FOR EACH METHOD

Test Method	Particulate Concentration, Gr/DSCF					
	Total Part., Incl. Cond.		Total Condensibles		Part. on Filter (s)	
	Mean, μ	Std. Dev., σ	Mean, μ	Std. Dev., σ	Mean, μ	Std. Dev., σ
EPA Method 5 (16 Tests)	.0068	.0033	.0044	.0032	.0023[1]	.0018
Cascade Impactor (13 Tests)	.0035	.0019	.0029	.0015	.0005	.0007
IKOR Monitor (20 Tests)	--	--	--	--	.0018	.0009
Duct Background EPA Method 5 (2 Tests only)	.0075	.0007	.0035	.0007	.0035[1]	.0007
Duct Background IKOR Monitor (4 Tests)	--	--	--	--	.0025	.0013
Room Background Hi-Vol Near Booth (11 Tests)	--	--	--	--	.0019	.0011
Room Background Hi-Vol in Production Area. (7 Tests)	--	--	--	--	.0036	.0025

[1] Includes Probe Wash. (Probe wash does not apply to other test methods.)

TABLE 5-12

SUMMARY OF STATISTICAL ANALYSIS
TOTAL OF 10 TESTS: ALL METHODS ISO-KINETIC AND ALL METHODS WERE RUN CONCURRENTLY

Test Method	Particulate Concentration, Gr/DSCF					
	Total Part., Incl. Cond.		Total Condensibles		Part. on Filters	
	Mean, μ	Std. Dev., σ	Mean, μ	Std. Dev., σ	Mean, μ	Std. Dev., σ
EPA Method 5	.0064	.0024	.0036	.0020	.0027[1]	.0020
Cascade Impactor	.0031	.0019	.0025	.0013	.0005	.0007
IKOR Monitor					.0023	.0010
Duct Background EPA Method 5 (2 tests only)	.0075	.0007	.0035	.0007	.0035[1]	.0007
Duct Background IKOR Monitor (4 tests)	--	--	--	--	.0025	.0013
Room Background Hi-Vol near booth (4 tests)	--	--	--	--	.0027	.0006
Room Background Hi-Vol in production area (3 tests only)	--	--	--	--	.0052	.0029

[1] Includes probe wash. (Probe wash does not apply to other test methods.)

greater than 95 percent. This statistical analysis is presented in Table 5-13a for total particulate concentration, in Table 5-13b for total condensible concentration, and in Table 5-13c for the solid particulate concentration collected on the filter(s).

5.4.3.1 Background Tests

The three comparative test methods were run concurrently at isokinetic conditions for 10 tests. These 10 tests were conducted over a four day period. During those four days a total of four hi-vol tests near the booth for background testing spanned the production duration for mold pouring. Several mold pouring emission tests were often conducted during one hi-vol test. Duct background data was provided by two isokinetic tests with the EPA Method 5 train. These tests occurred in the morning prior to mold pouring.

5.4.3.2 EPA Method 5 Test Comparison

From Table 5-12 it can be observed that there was no statistically significant difference between the duct tests by EPA Method 5 and the:

1. Duct background "reference" that was determined by EPA Method 5 and the continuous monitor in the duct.
2. Continuous monitor tests ("particulate on filter").
3. Room background "reference" that was established by the hi-vol tests near the booth.

The EPA Method 5 duct results were higher than the cascade impactor results. Compared to the cascade impactor, the following confidence intervals were obtained for the difference in results:

TABLE 5-13 (a)

DIFFERENCES IN TEST METHOD PERFORMANCES
TOTAL PARTICULATE CONCENTRATION, GR/DSCF

	Statistical Analysis				
	"t" Tests		"f" Tests		
Comparison of Methods	Interval	Confidence	"f" Ratio	Critical "f" & % Confidence	Remarks
Cascade Impactor EPA Method 5 to-	0.0033±0.0029	99%	12.0	8.3; 99%	Significant difference confirmed by "f" test.
Duct Backgrounds by EPA Method 5	None	99%	0.6	10.0; 99%	No statistical difference confirmed by "f" test.
Cascade Impactor to- Duct Background by EPA Method 5	0.0044±0.0026	99%	10.1	10.0; 99%	Significant difference of lower Cascade results confirmed by "f" test.

TABLE 5-13 (b)

DIFFERENCES IN TEST METHOD PERFORMANCES
TOTAL CONDENSIBLES CONCENTRATION, GR/DSCF

Comparison of Methods	Statistical Analysis				Remarks
	"t" Tests		"f" Tests		
	Interval	Confidence	"f" Ratio	Critical "f" & % Confidence	
Cascade Impactor EPA Method 5 to -	None	99%	2.3	8.3; 99%	No statistical difference confirmed by "f" test.
Duct Background by EPA Method 5	None	99%	0.3	10.0; 99%	No statistical difference confirmed by "f" test.
Cascade Impactor to - Duct Background by EPA Method 5	None	99%	1.3	10.0; 99%	No statistical difference confirmed by test.

TABLE 5-13 (c)

DIFFERENCES IN TEST METHOD PERFORMANCES; PARTICULATE ON FILTER(S) CONCENTRATION, GR/DSCF

	Statistical Analysis				
	"t" Tests		"f" Tests		
Comparison of Methods	Interval	Confidence	"f" ratio	Critical "f" & % confidence	Remarks
EPA Method 5 (10 Tests) to - ° Cascade Impactor (10 Tests)	0.0022±0.0020	99%	10.8	8.3; 99%	Significant difference confirmed by "f" test.
° Continuous Monitor (10 Tests)	None	99%	0.3	8.3; 99%	No statistical difference confirmed by "f" test.
° Duct Background, By EPA Method 5 (2 Tests Only)	None	99%	0.6	10.0; 99%	Ditto
° Duct Background, By Continuous Monitor (4 Tests only)	None	99%	0.03	9.3; 99%	Ditto
° Room Background At Booth, By Hi-Vol. (4 Tests only)	None	99%	0.01	9.3; 99%	Ditto
Cascade Impactor to - ° Continuous Monitor	0.0018±0.0011	99%	2.16	8.3; 99%	Significant difference of lower Cascade results confirmed by "f" test.
° Duct Background By Method 5	0.0030±0.0023	99%	21.6	8.3; 99%	Ditto
° Duct Background By Continuous Monitor	0.0020±0.0019	95%	14.3	4.8; 95%	Ditto
° Room Background At Booth, By Hi-Vol.	0.0022±0.0012	99%	29.8	9.3; 99%	Ditto
Continuous Monitor to - ° Duct Background By EPA Method 5	None	99%	2.5	10.0; 99%	No statistical difference confirmed by "f" test.
° Duct Background, By Continuous Monitor	None	99%	0.1	9.3; 99%	Ditto
° Room Background At Booth, By Hi-Vol.	None	99%	0.6	9.3; 99%	Ditto
Duct Background, By EPA Method 5 to - ° Duct Background, By Continuous Monitor.	None	99%	0.5	21.2; 99%	No statistical difference confirmed by "f" test.
° Room Background At Booth, By Hi-Vol.	None	99%	0.6	21.2; 99%	Ditto
Duct Background, By Continuous Monitor to - ° Room Background At Booth, By Hi-Vol.	None	99%	0.2	13.8; 99%	No statistical difference confirmed by "f" test.

1. Total particulate (99 percent confidence interval) - 0.0033 ± 0.0029 gr/dscf
2. Total condensibles (99 percent confidence interval) - no statistically significant difference.
3. Particulate on filter(s) (99 percent confidence interval) - 0.0022 ± 0.0020 gr/dscf

Thus, the most similar results between the two methods were the total condensibles. From the mean values of Table 5-15, total condensibles represented 80 percent of the total sample collected by the cascade impactor train and 56 percent of the total sample collected by the EPA Method 5 train. The higher percentage of condensibles in the cascade train can be attributed to collecting insufficient dry particulate on each filter stage (as will be discussed in Section 5.4.3.3).

In summary, process emissions in excess of the background concentration were not detected by the EPA Method 5 train. Statistically, there was no significant difference between the EPA Method 5 train results and the continuous monitor results. The EPA Method 5 results were statistically higher than the cascade impactor results, with the exception of total condensibles.

5.4.3.3 Cascade Impactor Test Comparison

Particulate results from the continuous monitor are limited to a dry particulate (listed as "particulate on filter" in Table 5-13c) since there is no condensibles train presently designed for the unit. The results obtained showed no statistically significant difference when compared to the:

1. EPA Method 5 dry particulate duct test results.
2. Background results obtained in the duct by:
   - A. EPA Method 5
   - B. Continuous monitor
3. Background results obtained in the room by hi-vol tests near the booth.

The total particulate 99 percent confidence interval for the true difference between the averages of the methods was:

1. 0.0033 ± 0.0029 Gr/DSCF when compared to EPA Method 5
2. 0.0018 ± 0.0011 Gr/DSCF when compared to the continuous monitor ("Particulate on Filter").

Several conditions must be discussed pertaining to the cascade impactor results. First, no traversing was done. This may result in lower concentrations than EPA Method 5.

Secondly, the particulate catch on individual filters was frequently not detectable or lower than the amount that is recommended by the impactor's manufacturer (minimum of 0.2 to 0.5 mg per filter) for reliable results. A longer test time to collect more particulate on the filters may be required, but this was prevented by the constraints of test timing. The range of total dry particulate collected for the impactor tests was only 0.5 to 2.75 mg, whereas the total tare weight of cascade filters was approximately 850 mg. Thus the greatest collection rate only represented about 0.3 percent of the total tare weight. The amount collected and the accuracy of detecting that amount leads to the conclusion that no meaningful particle size distribution results were obtained and that the total dry particulate results may be erroneous.

Thus, in applying the cascade impactor procedure to the quasi-stack strategy, a process emission concentration and duration must be substantially greater than this particular mold pouring operation to provide meaningful results.

5.4.3.4 Continuous Monitor Test Comparison

Particulate results from the continuous monitor are limited to a dry particulate (listed as "Particulate on Filter" in Table 5-13c) since there is no condensibles train presently designed for the unit.

The results obtained showed no statistically significant difference when compared to the:

1. EPA Method 5 dry particulate duct test results
2. Background results obtained in the duct by:
    - A. EPA Method 5
    - B. Cascade Impactor
3. Background results obtained in the room by Hi-vol tests near the booth.

The continuous monitor results were higher than the cascade impactor results (a 99 percent confidence interval of 0.0018 ± 0.0011 gr/dscf was obtained).

From the continuous monitor trace it was found that substantial mold pouring particulate emissions occurred at the time of pouring, and, in a matter of one or two minutes, the emissions returned to the genera background levels for the remainder of the test (30 minutes total for particulates). This is clearly illustrated by Figures 5-10 and 5-11. Of all the particulate emission testing procedures that were used during this program, the continuous monitor was the only procedure that was ca-

FIGURE 5-10

TEST 17: CONTINUOUS MONITOR TRACE

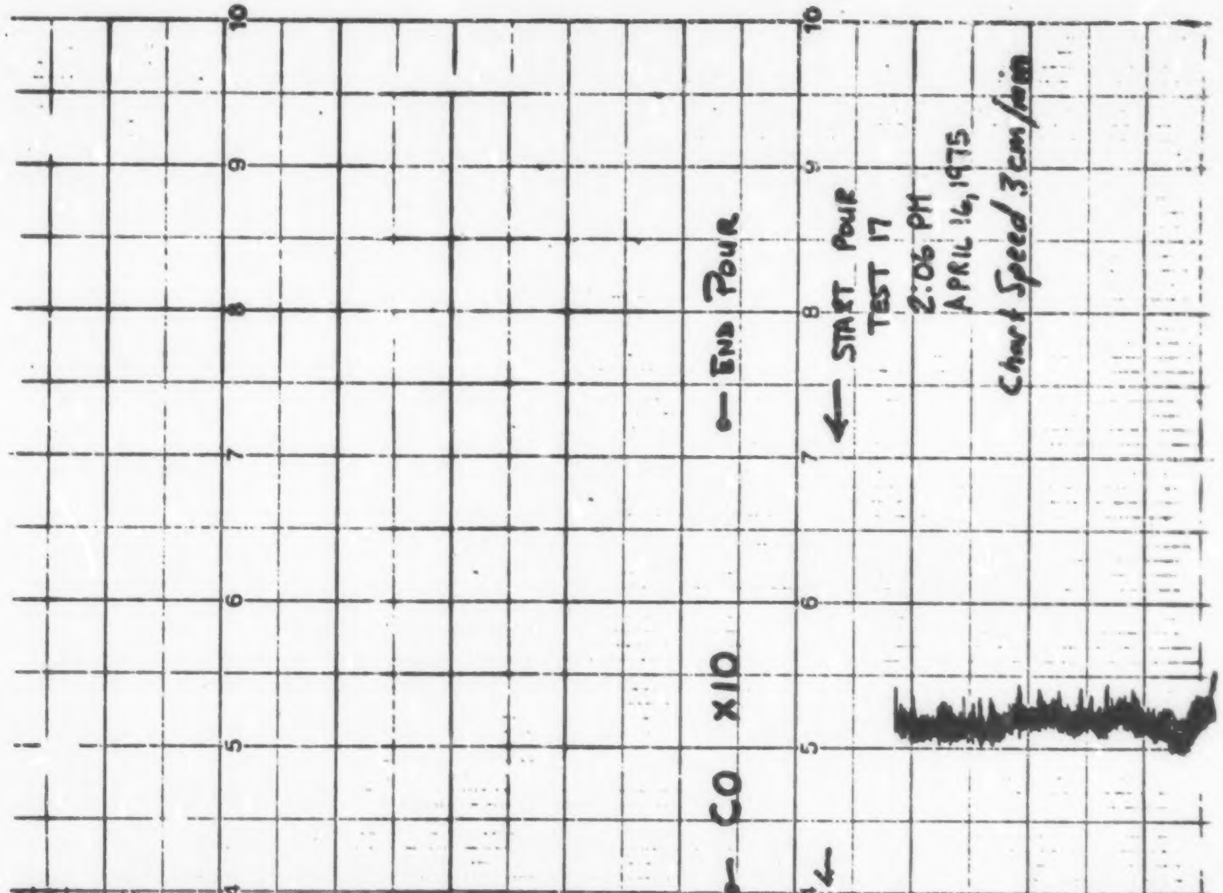
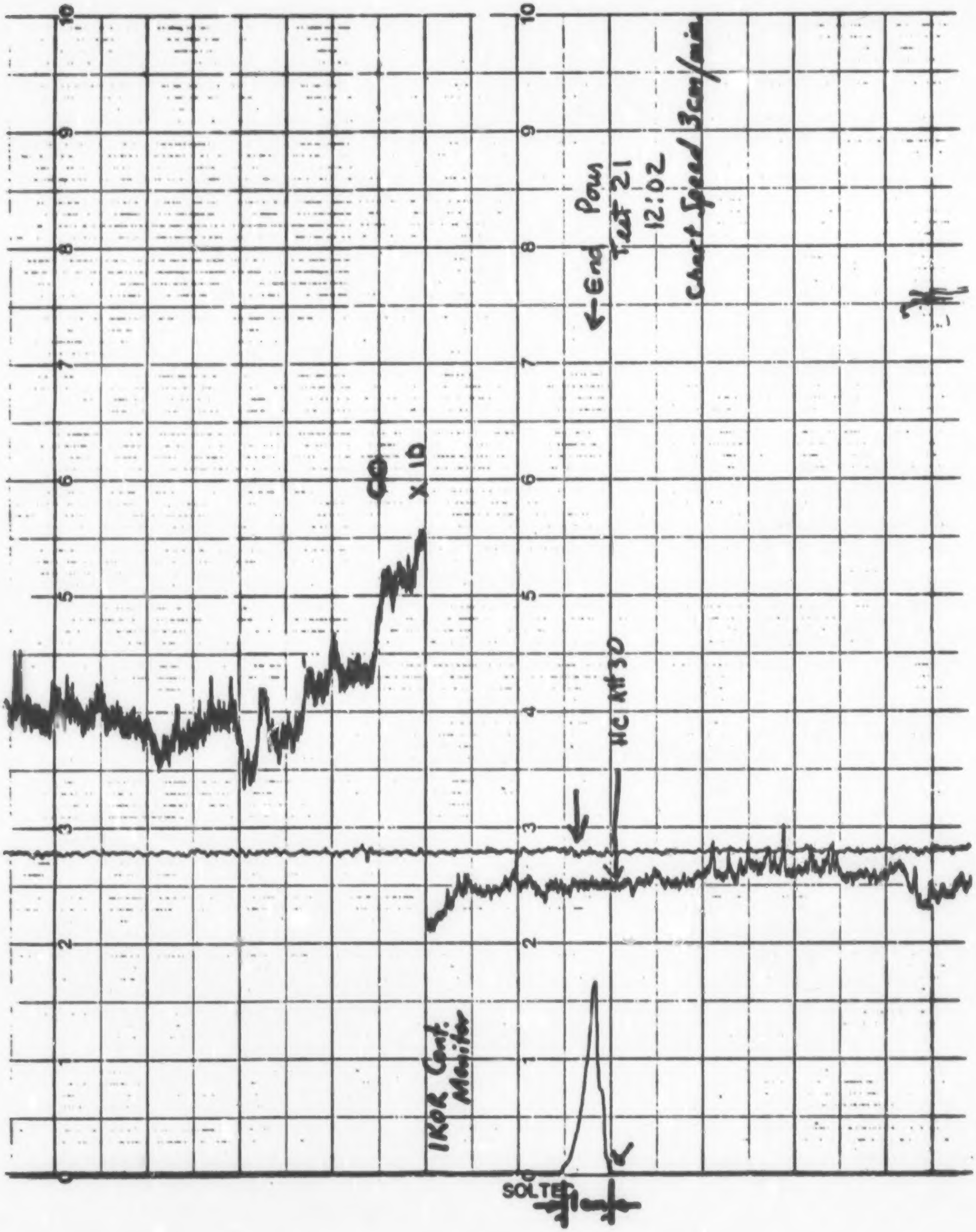


FIGURE 5-11

TEST 21: CONTINUOUS MONITOR TRACE



pable of defining (either quantitatively or qualitatively) this brief, large emission at the time of mold pouring. The EPA Method 5 and cascade impactor procedures averaged that short emission excursion over a 30 minute sampling period, in this case and thus reduced the detectability of this emission.

From Table 5-11, the mean concentration that was determined by continuous monitor was 0.0018 gr/dscf with a standard deviation of 0.0009 (20 tests). Figures 5-10 and 5-11 show that the concentration due to the emissions at the time of pouring may be an order of magnitude greater than the general background level, or approximately 0.02 gr/dscf (at 8500 scfm). This brief emission excursion for one mold is average by EPA Method 5 and cascade impactor procedures over the 30 minute test period. This emission excursion has greater significance when it is considered as an accumulative emission for the large number of molds that are typically poured per day in this foundry.

Thus, for a mold pouring operation such as this where the molds are stationary at all times and the particulate emissions only occur briefly, the EPA Method 5 and cascade impactor procedures average the emissions over a long period of time and essentially monitor the background concentration. A continuous monitor is required to define the emission excursion.

The EPA Method 5 and cascade impactor procedures may be suitable to mold pouring operations where numerous molds are conveyed to a stationary pouring station in a short period of time. Monitoring particulate concentrations in excess of the background condition would be more likely to occur than in the case tested for this program, and there would be more of a particulate catch for particle size distribution and composition analysis.

5.4.3.5 Test Setup Limitations

As discussed earlier, the nature of the mold pouring operation was such that a large booth and large flow volume was required to capture the fugitive emissions. The large flow volume probably induced a convective air current at a considerable distance from the booth. Any activity adjacent to the booth such as core cleaning, sand compacting, or vehicle traffic (all of which occurred regularly during the testing), could generate local fugitive emissions that might enter the booth. Thus, a general activity background level would be monitored by the sampling apparatus in the duct. That activity emission level may be as significant as the 30 minute averaged emissions from the mold pouring and cooling operation itself. This is supported by the statistical comparisons discussed earlier.

5.4.3.6 Critique of Sampling Methods

In Section 5.4.3.4 a discussion was given of the significance of the emission excursion above general background concentrations at the time of mold pouring. The continuous monitor was the only method that defined that excursion. Unfortunately, the continuous monitor did not have the provision for monitoring total condensibles, which comprised the major portion of the particulate fugitive emissions (Section 5.4.3.2). A condensibles train designed specifically for the continuous monitor would have to be larger than the EPA Method 5 train since the sample flow volume is much greater. This would constitute a hybrid monitor that gave continuous dry particulate emissions and integrated condensible material emissions.

For this application, the cascade impactor results were questionable. For more concentrated emissions and longer sampling times, this method may be a suitable approach for providing particle size distribution and total particulates, including condensibles. The short sampling times and generally low emissions encountered during this program led to the conclusion that the EPA Method 5 train is probably the best all-purpose method for particle size distribution (by microscopy, which will be discussed in Section 5.4.3.7), total particulates including condensibles, and particle composition (which will be discussed in Section 5.4.3.8. The major limitation of the EPA Method 5 for this application was the inability to determine brief excursion emissions, as described above.

5.4.3.7 Presentation of Particle Sizing Data

The cascade impactor test results were eliminated from consideration for particle size analysis for the reasons outlined in Section 5.4.3.3. As a backup for the cascade impactor, a membrane filter was used in the EPA Method 5 train setup. Particle size distribution by count was determined by microscopy. Table 5-14 presents the results of that analysis.

The statistical analyses of the 16 isokinetic emission tests and the two EPA Method 5 duct background tests (also isokinetic) are presented in Tables 5-15 and 5-16. Mean values and standard deviations of the particle size distribution by percent count are presented in Table 5-14.

TABLE 5-14

PARTICLE SIZE DISTRIBUTION (% BY COUNT): EPA METHOD 5

Test No.	% Isokinetic	Distribution		
		% <1μ	% 1-3μ	% >3μ
1	68	80.9	12.9	6.2
2	60	82.9	13.7	3.4
3	62	80.8	14.6	4.6
4	61	--	--	--
5	62	74.7	21.4	3.9
6	61	71.7	25.8	2.5
B1	--	--	--	--
7	58	67.8	30.3	1.9
B2	61	70.4	27.3	2.3
8	101	71.7	25.9	2.4
9	99	71.9	25.9	2.2
10	98	60.9	35.9	3.2
11	100	66.9	31.3	1.8
12	101	63.0	34.9	3.0
13	102	64.0	34.0	2.0
14	104	62.0	35.0	3.0
15	103	65.0	32.0	3.0
16	102	65.0	32.0	3.0
17	100	73.0	26.0	1.0
B3	100	54.0	41.0	5.0
18	100	57.0	40.0	3.0
19	103	69.0	29.0	2.0
20	104	76.0	23.0	1.0
B4	99	50.0	44.0	6.0
21	103	54.0	33.0	3.0
22	102	78.0	20.0	2.0
23	103	75.0	23.0	2.0

TABLE 5-15

PARTICLE SIZE DISTRIBUTION (% BY COUNT): MEAN VALUES AND STANDARD DEVIATION

Tests	Distribution	$\bar{y}$, Mean	σ, Std. Deviation
16 Isokinetic Emission Tests (p.m.)	<1μ	67.03%	6.91%
	1-3μ	30.00	5.53
	>3μ	2.35	0.72
2 Isokinetic Duct Background Tests (a.m.)	<1μ	52.00%	2.83%
	1-3μ	42.50	2.12
	>3μ	5.50	0.71

TABLE 5-16

PARTICLE SIZE DISTRIBUTION (% BY COUNT): STATISTICAL DIFFERENCES BETWEEN PROCESS EMISSIONS AND BACKGROUND CONDITION

	Statistical Analysis				
	"t" Tests		"f" Tests		
Distribution	interval	Confidence	"f" ratio	Critical "f" & % confidence	Remarks
<1μ	15.03% ± 9.81%	99%	8.91	8.53; 99%	Statistical difference confirmed by "f" test
1-3μ	12.50% ± 7.14%	99%	9.60	8.53; 99%	Ditto
>3μ	3.15% ± 2.30%	95%	34.13	4.49; 95%	Ditto

Table 5-15 presents the "t" test results as a confidence interval, as discussed in Section 5.4.3, and the "f" test results to confirm that a statistical difference between the sets of data existed.

From the analysis it can be concluded that there is a statistical difference between the process emissions (monitored in the afternoon) and the background condition (monitored in the morning). Approximately two thirds of the process emission particles were less than one micron in size, and approximately one third were in the one to three micron size range. This compares to the duct background condition of approximately half of the particles at less than one micron and about 40 percent between one and three microns in size.

As discussed above, there is a statistical difference between the process and background data. It can be concluded that a process emission particle characteristic, not a general background particle characteristic, was monitored; but, as discussed in Section 5.4.3.1, the concentration that was monitored by EPA Method 5 did not exceed the general background concentration.

5.4.3.8 Particulate Composition

The average particulate catch on the EPA Method 5 membrane filters was only about 1 mg for the isokinetic tests. For most laboratories and standard analytical methods this is an insufficient particulate sample for analysis of composition by percent weight. Longer sampling time to obtain more of a particulate catch was ruled out since most of the emissions occurred in a one to two minute period at the time of pouring, as discussed in Section 5.4.3.4.

Analytical methods described in Section 5.4.2 were employed despite the insufficient sample. The accuracy of the results prevents reporting meaningful data for composition by percent weight, but it can be reported that traces of SiO_2, Fe, $SO_4^=$, and NO_3^- were detected on most of the filters.

To improve particulate composition results for operations such as the one tested, entire filters rather than filter fractions must be used for each analysis. For operations with molds conveyed to a stationary pouring station, both entire filters and longer sampling periods should be used to improve particulate composition results.

5.4.4 Evaluation of Hydrocarbon Concentration Data

The layout of molds on the foundry floor included double rows of molds along the length of the bay. Pouring began, as shown in Figure 5-12, at approximately noon each day at the cupola area opposite the test booth. Pouring progressed along one row towards the booth, then started on the second row, and again progressed toward the booth. Pouring was usually completed by 2:30 or 3:00 p.m. each day. Table 5-9 presents a detailed description of foundry activities during each test.

Table 5-17 presents the total hydrocarbon (methane basis) concentration data that was obtained as outlined in Section 5.4.4. Concentrations are reported from the daily plots at 30 minute intervals between noon and 3:00 p.m. for each of the nine test days. The mean concentration and standard deviation was calculated for each time, tabulated in Table 5-17, and presented graphically in Figure 5-13.

Normally three tests (mold pourings) were conducted at the test booth

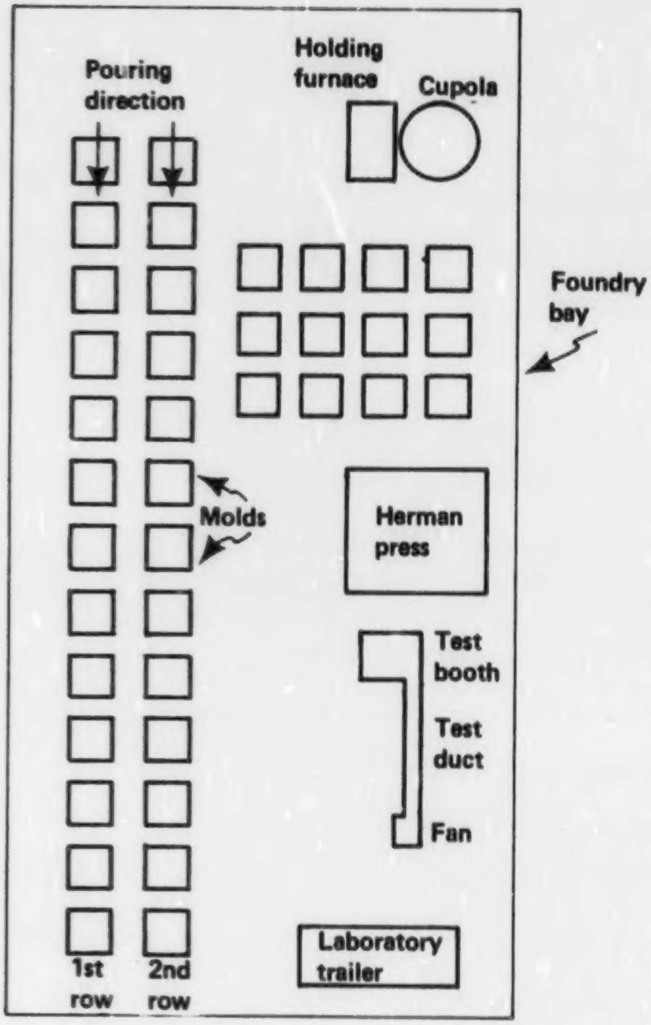

Pouring direction
Holding furnace
Cupola
Foundry bay
Molds
Herman press
Test booth
Test duct
Fan
Laboratory trailer
1st row
2nd row

Fig. 5-12. Layout of molds.

TABLE 5-17

TOTAL HYDROCARBON CONCENTRATION
(ppm as CH_4)

Day		Total Hydrocarbons, ppm (as CH_4)									Statistical Analysis	
		4/7/75	4/8/75	4/9/75	4/10/75	4/14/75	4/15/75	4/16/75	4/17/75	4/21/72	Mean HC Conc., ppm (as CH_4)	Std. Dev., HC ppm (as CH_4)
Time	12:00	48	5	7	4	22	20	12	—	82	25	27
	12:30	46	14	10	17	96	22	12	--	60	34.6	30.6
	1:00	34	25	38	231	62	c.200	c.200	48	46	98.2	85.2
	1:30	30	29	20	70	26	56	50	56	66	44.8	18.7
	2:00	28	29	16	48	70	41	20	48	76	41.8	21.0
	2:30	58	62	30	46	39	54	72	70	72	55.9	15.1
	3:00	64	47	50	86	96	--	50	72	68	66.6	17.8

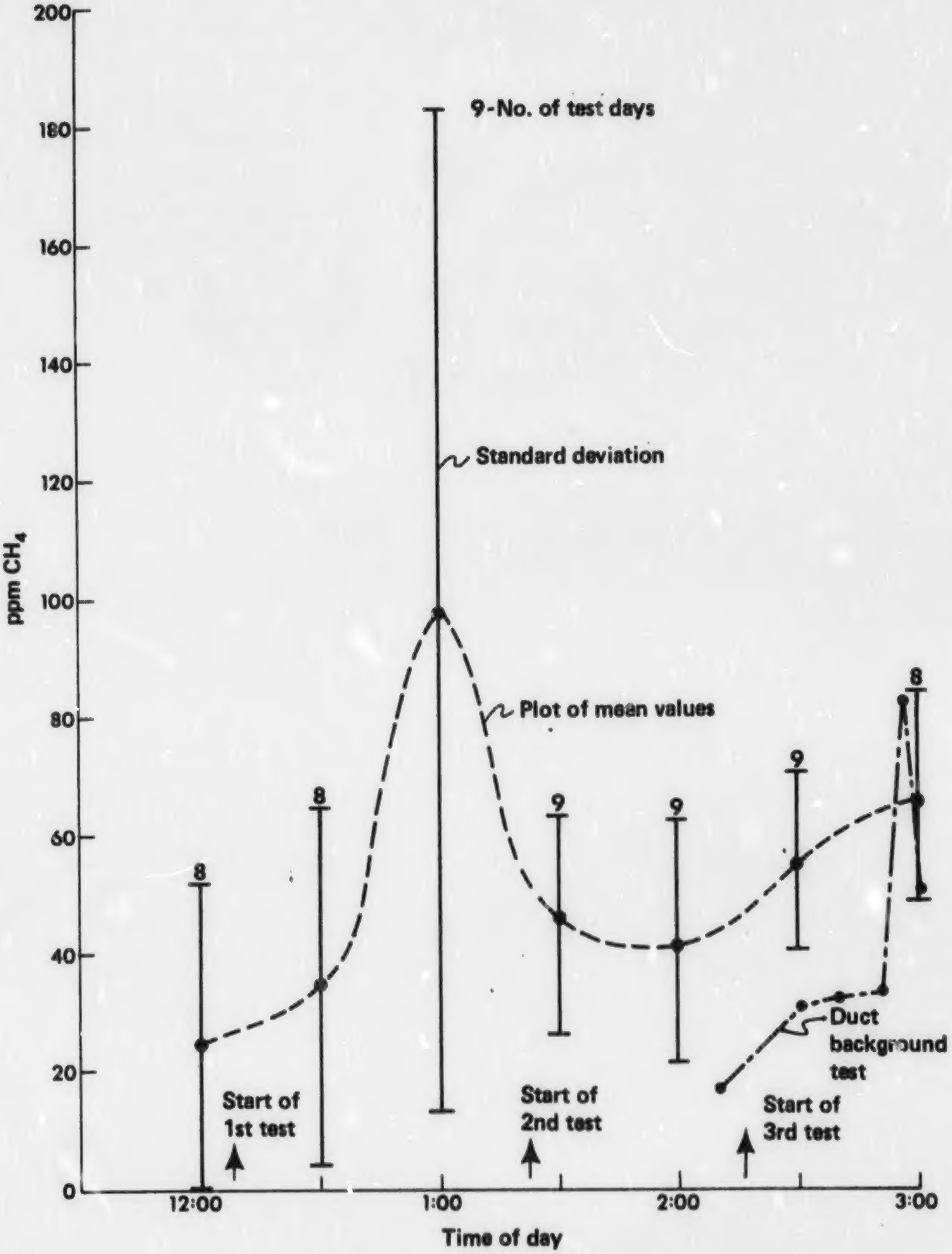


Fig. 5-1[illegible] Plot of mean half-hour hydrocarbon concentrations for period April 7-21, 1975.

each day. The average start time for the three tests is shown in Figure 5-13. One background test was conducted in the duct when no mold was in the booth. This test is also presented in Figure 5-13, and it generally follows the pattern of the mold pouring tests.

It can be observed from Figure 5-13 that two peaks occurred during the day. Daily observations determined that these peaks occurred about 50 minutes after pouring activity in the vicinity of the booth or the adjacent Herman press--not necessarily after a mold was poured in the test booth. Entries in Table 5-17 show that pouring occurred near the booth (first row pouring) and Herman press area between 12:10 and 12:30 on April 8, 10, and 21 (booth) and April 15 and 16 (Herman press). Figure 5-13 illustrates the first peak occurring from this pouring activity about 1:00 p.m. The second row near the booth was poured between 2:00 and 2:45 on April 9, 14, 16, 17, and 21, as recorded in Table 5-17. The second peak of Figure 5-13 appears at 3:00 p.m. or later, after pouring had been completed.

It can thus be concluded that HC monitoring essentially defined a background or general foundry activity condition and isolation of a specific mold or the emissions contribution of one mold was not distinguished from general background concentrations.

5.4.5 Evaluation of Carbon Monoxide Concentration Data

Table 5-18 presents the carbon monoxide concentration data that was obtained as outlined in Section 5.4.1.8. Concentrations are presented from the daily plots at 30 minute intervals between noon and 3:00 p.m. The mean concentration and standard deviation was calculated for each time,

TABLE 5-18

CARBON MONOXIDE CONCENTRATION DATA, PPM

	Day	Carbon Monoxide Concentration, ppm								Statistical Analysis	
		4-7-75	4-8-75	4-9-75	4-10-75	4-14-75	4-16-75	4-17-75	4-21-75	Mean CO Concentration, ppm	Standard Deviation
	12:00	27	5	5	4	9	5	—	17	10.3	8.7
	12:30	28	31	26	25	50	21	—	14	27.9	11.2
	1:00	28	24	28	44	31	27	31	12	28.1	8.8
Time	1:30	30	25	20	35	19	20	24	12	23.1	7.1
	2:00	32	25	20	35	34	15	23	18	25.3	7.6
	2:30	66	85	55	46	56	65	45	20	54.8	19.0
	3:00	66	60	36	48	43	38	70	22	47.9	16.6

tabulated in Table 5-18, and presented graphically in Figure 5-14. A background test was also plotted on Figure 5-14.

From Figure 5-14 it can be observed that as in the case of total hydrocarbons, there are two peaks again appearing. From the pouring activity description given in Table 5-18 and Table 6-9, it was noted that CO concentrations increased almost immediately after pouring occurred near the booth and in the adjacent Herman press area. The one duct background test also closely followed the pattern of Figure 5-14.

Thus, it can be concluded that a general background or activity condition was monitored during the CO testing. Isolation of a specific mold or the emissions contribution of one mold was not distinguishable from general background concentrations.

As in the case of the HC measurements, this procedure for CO monitoring may be more suited to the foundry with a central pouring station(s). If quasi-stack procedures are to be applied to the type of foundry operation that was tested, the test mold will have to be isolated better from general room activity. If this is not possible, a broader approach for defining emission concentrations will have to be employed, such as roof monitoring or traditional industrial hygiene measurement techniques.

5.5 Task V - Issue a Technical Manual

After revision and thorough testing in the field, a final draft of the field test procedure was issued.

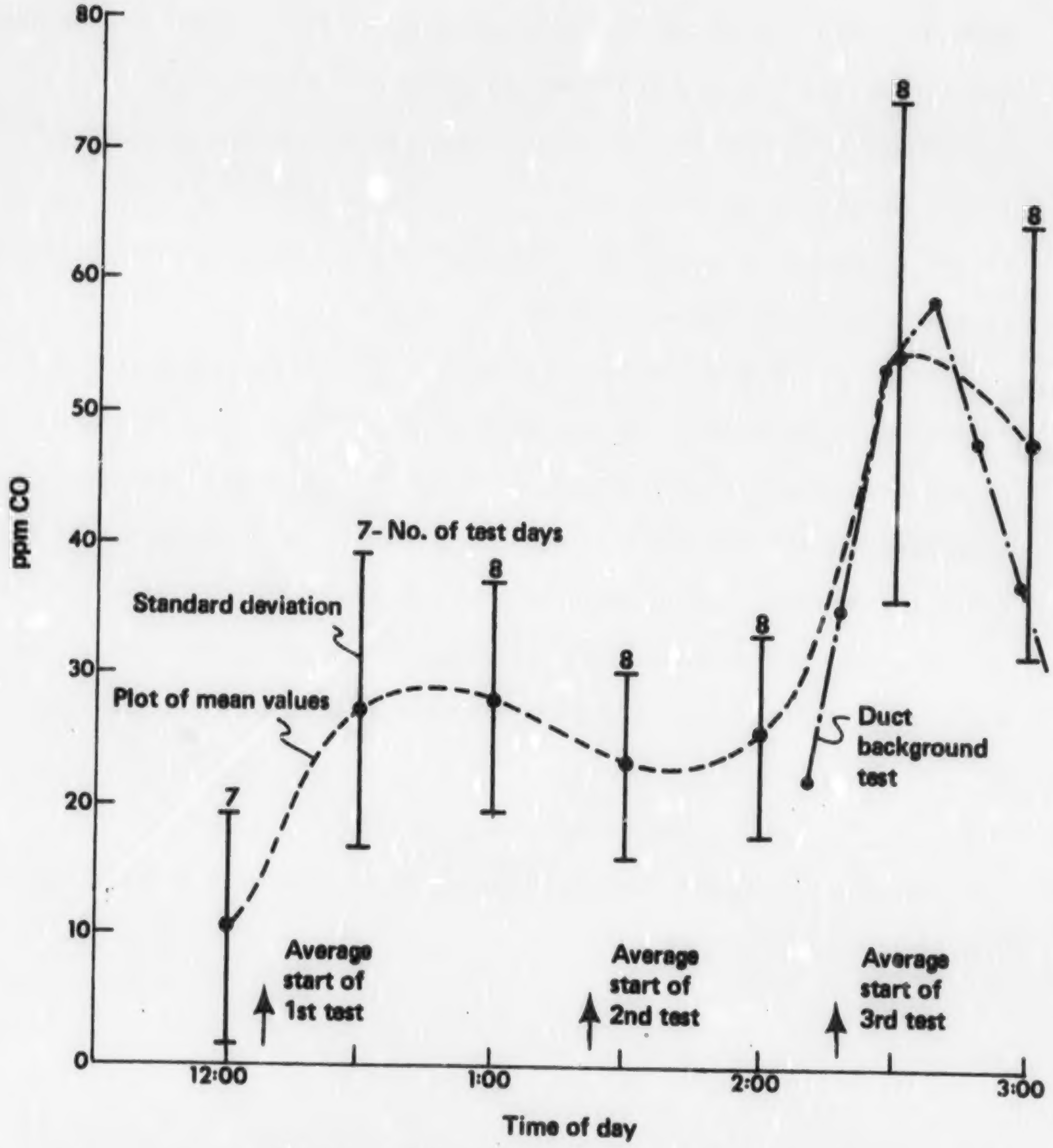


Fig. 5-14. Plot of mean half-hour carbon monoxide concentrations for period April 7-21, 1975.

5.6 Units of Measure

Although it is the policy of EPA to use the metric system for qualitative descriptions, the British system is generally used in this report. Appendix K contains a conversion table to aid readers who wish to use metric units where only British units are cited.

APPENDIX A

LITERATURE REFERENCES TO FUGITIVE EMISSIONS

1. "Processing Emissions and Occupational Health in the Ferrous Foundry Industry," C. E. Bates, L. D. Scheel, AIHA Journal, 452, August, 1974.

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20. "Control of Particulate Emissions from Lime Plants - A survey," L. J. Minnick, JAPCA, 195, April, 1971.

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22. "Source Control of Air Emissions," H. F. Elkin, R. A. Constable, Hydrocarbon Processing, 51, 113, October, 1972.

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APPENDIX B

SUMMARY OF TRADE ASSOCIATION/INDUSTRY/POLLUTION CONTROL AGENCY CONTACTS ON FUGITIVE EMISSIONS

SUMMARY OF TRADE ASSOCIATION/INDUSTRY/POLLUTION CONTROL AGENCY

CONTACTS ON FUGITIVE EMISSIONS

	Organization	Contact	Results
1.	National Crushed Stone Assn.	Mr. Rick Renninger V.P. Operations	Contributed reports, reprints, EPA proposal, all on fugitive dust in the stone industry. Discussed subject in person at office.
2.	American Iron & Steel Inst.	Mr. Ed Lally	Referred TRC to AISI environmental committee. Contributed coke oven emission article, steel making flowsheets on office visit.
3.	Aluminum Assn.	Dr. William Balgord Manager Env. Services	Requested letter to environmental committee. Suggested NIOSH data as being useful to us. Visited office for discussion.
4.	Asphalt Institute	Mr. V. Piuzinauskas Chem Engineer	Discussed report on hydrocarbon emissions done for them by Esso. Visit was made and data was discussed before report issued. We will get copy.
5.	American Foundrymen's Assoc.	Mr. Hulsen	Discussed problems of cupola charging and pouring. Suggested other contacts. Also discussed emissions from mold making and pouring.
6.	Kennecott Copper Corp.	Dr. Fred Templeton	Will contribute their data on fugitive emissions at Utah smelter. Would like meeting with TRC/EPA.
7.	Bethlehem Steel Co.	Mr. Tom Keller	Discussed Roof Monitor Sampling Methods.
8.	Rubber Manufacturers	Mr. Frank T. Ryan Director, Env. Health Safety Affairs	TRC may make presentations to environmental committee. Other contacts suggested who may supply data.
9.	EPA Region III (Philadelphia, Pa.)	Mr. Lou Fallison	Suggested other contacts. Thinks dust blowing off open hearth roofs is fugitive. BOF Tap and charge emissions not well controlled.
10.	Arizona Div. of Air Pollution Control	Mr. Mead Sterling	Smelters have 10-25% of SO_2 as fugitive emission. Furnace leakage a problem. Storage pile fugitive dust.
11.	Texas Air Control Board - El Paso	Mr. Jim Shoults	Fugitive SO_2 at smelters 5-10% of total. Storage piles a problem -- need to build structures over them.
12.	Pa. Dept. of Env. Resources Allegheny Cty.	Mr. Feigenbaum	Most coke oven emissions are fugitive. They have no data, but air quality near coke plants known.
13.	Bay Area Air Pollution Control District-California	Mr. Warren Crouse	Uses API data as hydrocarbon emission guidelines. No new data known.
14.	Los Angeles Air Pollution Control District-California	Mr. William Krenz	Uses API data as hydrocarbon emission guidelines. No new data known.

APPENDIX C

MATRIX CHARTS USED TO IDENTIFY AND CHARACTERIZE FUGITIVE EMISSION SOURCES

KEY TO PROCESS STEP HEADINGS ON MATRIX CHARTS

List process or industry, whichever provides best description. For each process step (described below), enter symbol (from attached list) describing character of emissions.

1. Material Delivery - Emissions from transfer of raw material from transport mode to plant storage area (e.g., carbon black delivery by railroad car to tire plant).
2. Material Storage - Raw material emission from process storage areas (e.g., sand blown from cement plant pile, evaporation of hydrocarbons from oil storage tanks).
3. Material Transfer - Emissions in getting materials from storage to process use point (e.g., coal dust from conveyors in coal washing plant).
4. Mixing and Grinding - Emission from putting ingredients together. Also sizing and classifying emissions in this category (e.g., mixing of lime and silica for cement manufacturing).
5. Ingredient Preparation - Emissions from special steps needed to make a prime ingredient of the process (e.g., drying of stone for use in asphalt paving, mold making for iron casting).
6. Reactor Charging - Emissions during opening of reactor to add raw materials (e.g., blast furnace loading with iron, limestone and coke).
7. Process Leakage - Leaks of main process system where emissions are involved (e.g., coke oven door seal leakage).
8. Enclosure Leakage - Open building emissions not treated by pollution control air handling systems (e.g., dust blown out of windows or doors in foundry due to insufficient hooding).
9. Reactor Discharge - Emissions when product is removed from main reactor (e.g., tapping of a blast furnace).
10. Final Product Preparation - Any emissions from size reduction or final forming needed to make usable product (e.g., cement clinker grinding to a powder)
11. Solvent Evaporation - Emissions from uncontrolled solvent removal operations (e.g., drying of ink in printing).
12. Ground Dust - Dust emissions not primarily from the process but made airborne by wind or traffic near or in the plant (e.g., dust from truck deliveries on dirt roads).

13. Waste Transfer - Emissions from transfer of waste from process to storage point. This includes waste captured by all forms of pollution control equipment (e.g., conveying of slag to slag pit from blast furnace).

14. Waste Storage - Emission from waste in a disposal area (e.g., vapors from wastewater settling pond).

15. Product Transfer - Emission during transfer of product from process line to storage area or transport (e.g., conveying of grain to storage silos).

16. Product Storage - Emissions from product during storage before delivery to user (e.g., vapors from creosoted telephone pole piles).

17. Product Packaging - Emissions in going from process or storage to shipping or final retailing or wholesaling containers (e.g., fertilizer bagging).

18. Mining and Blasting - Emissions from excavation, material breaking and explosive blasting within mining type operations (e.g., dust plumes from blasting).

EXPLANATION OF SYMBOLS USED ON MATRIX CHARTS TO DESCRIBE EMISSIONS CHARACTER

Symbol	Meaning	Particle Size
M	Mining	>2μ
m	Mining Dust	<2μ
S	Stockpile Dust	>2μ
s	Stockpile Dust	<2μ
T	Truckload and Road Dust*	>2μ
t	Truckload and Road Dust*	<2μ
C	Crushing and Grinding Dust	>2μ
c	Crushing and Grinding Dust	<2μ
D	Transfer Material Dust	>2μ
d	Transfer Material Dust	<2μ
O	Organic Particulate (Solid)	>2μ
o	Organic Particulate (Solid)	<2μ
P	Metallic Particulate	>2μ
p	Metallic Particulate	<2μ
W	Aqueous Mist	>2μ
w	Aqueous Mist	<2μ
L	Organic Particulate (Liquid)	>2μ
l	Organic Particulate (Liquid)	<2μ
G	Odoriferous Gas	
g	Gas	
V	Odoriferous Vapor	
v	Vapor	
R	Reactive Gas Emission	
r	Reactive Vapor Emission	
F	Agricultural Field Dust	>2μ
f	Agricultural Field Dust	<2μ
B	Smoke from Burning	
E	Dust from Pollution Control Equipment	>2μ
e	Dust from Pollution Control Equipment	<2μ
Y	Fume or Process Dust from Reactors	>2μ
y	Fume or Process Dust from Reactors	<2μ
K	Livestock Generated Soil Erosion	>2μ
k	Livestock Generated Soil Erosion	<2μ
M	Mining & Blasting Dust	>2μ
m	Mining & Blasting Dust	<2μ

* Within Plant Confines

MATRIX CHART - FUGITIVE EMISSIONS SOURCES IDENTIFICATION AND CHARACTERIZATION

	PROCESS STEPS																			
INDUSTRY OR PROCESS	Material Delivery	Material Storage	Material Transfer	Mixing & Grinding	Ingredient Preparation	Reactor Charging	Process Leakage	Enclosure Leakage	Reactor Discharge	Final Product Preparation	Solvent Evaporation	Ground Dust	Waste Transfer	Waste Storage	Product Transfer	Product Storage	Product Packaging	Mining & Blasting	COMMENTS ON FUGITIVE EMISSIONS	COMMENTS ON CANDIDATE MEASUREMENT METHODS

APPENDIX D

MEASUREMENT OF FUGITIVE EMISSIONS - LITERATURE REFERENCES TO METHODS

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APPENDIX E

SAMPLE CRITIQUE OF SAMPLING METHODS

Two important parameters which are of prime interest in particulate emission measurements are particle size and material identification. Both are obtainable with a reasonable degree of accuracy under certain test conditions. Another parameter not readily obtained, however, is the instantaneous particulate emission rate from a fugitive source. Some progress has been made toward this goal in present techniques.

The methods of particulate fugitive emission measurement available involve seven basic techniques:

1. Standard filter impaction, collection, and weighing.
2. Piezoelectric mass detection.
3. Light scattering (Nephelometry of Lidar).
4. Radiation scattering (β gauges).
5. Electrostatic precipitation with controlled voltage.
6. Size selective impaction and weighing.
7. Adhesive impaction.

Filter Impaction. This technique collects most suspended particulate matter with the exception of fine aerosols and particles (< 0.1 μm) unless special filters are used which collect fine particles well at lower sample flow rates. The total particulate can be weighed with some degree of accuracy and analysis by instrumental or chemical techniques can readily be done. Some size distributions can be determined by use of a cyclone before the filter or two different porosity filters in a series. The filter catch can be examined under microscopes (optical and electronic) for determination of particle size. As a routine measure, however, this would be prohibitively expensive. Another problem of this technique is that it also gives only the *average* particulate concentration over the sampling period. If fugitive emission rates are time dependent, a lot of detail of the emission characteristics can be lost.

Piezoelectric. This technique accurately determines total particulate loadings of samples in very short time periods (< 1 second). It is, therefore, essentially on online continuous particulate matter monitor. There are two problems in that size distribution and material analysis are not possible. These are major disadvantages, since these are the critical criteria for fugitive particulate emissions. Some size discrimination could be done by suitable air sample prefiltration/separation, but this has limited applicability unless multiple instruments are used.

Light Scattering. Use of a Nephelometer allows the direct measurement of total particulate concentration and also the size distribution in a continuous online monitoring system. There would be no question that it met two important criteria except that these conclusions must be qualified. Experience has shown that this instrument must be precalibrated with the particle size and type which is to be examined. There are serious problems unless this is done. Also, dilution is required for measurements of concentrated particulate bearing gas streams, which introduces a possible error. The use of the Nephelometer is a question of how much pretesting can be tolerated to get good field data. Also, a material analysis is not obtained by this technique and indeed must be obtained before measurements can be made with the Nephelometer.

Another light scattering based system is Lidar, which remotely scans a sector of the atmosphere, and the amount of scattered beam detects the particulate concentration in that sector. The analysis of dust from fugitive sources can be made instantly, and entire areas can be "particulate mapped" over short time periods. Correlations with other methods have not been well-proven at the present, and commercial availability of equipment in in doubt.

Radiation scattering. The primary technique is to measure scattering of β radiation from a radioactive source by collected particulates. Since only small amounts of sample need to be collected, data acquisition is semi-continuous. Two different sample collection techniques have been employed. One uses a moving paper tape upon which the sample impacts and is then read with the β-scatter. The other uses a condensation chamber (water droplets trap the particulate) to concentrate the particulate on a glass surface, which is then read with the β-scatter. Both are readily adaptable for automatic sampling/readout. Hand portable instruments can be used so that areas of fugitive emission could be mapped by an operator walking through a specified sector. The method does require calibration with dust of the same type as being measured and also calibration of the individual instruments themselves.

Electrostatic precipitator. This is basically a small-scale version of an electrostatic precipitator and can be used to collect a representative sample on a suitable medium. Particle size and mass weight can be determined as easily as with a filter. Efficiency for fine particulate is better than a filter; a semi-continuous version is available for submicron particle sizing. A change in collector rod voltage is used to discriminate size. The techniques seem ideal for inorganic dust and aerosols, but no data on organics such as tars has been found. These techniques may be applicable to specific situations where size distribution of inorganic particulate needs to be measured.

Size selective impaction. A cascade impactor such as the Andersen Sampler can be used. It is reproducible and has been correlated to other techniques and also with known standards. It offers a reasonable range of size detection for studies of hazardous particulates. The problem is that it requires a large sample (plates are weighed) for accurate results and that this is only an average over the sample time period. It is, however, one of the easiest size discriminators to use under field test conditions.

Adhesive impaction. For size detection with low sample concentrations and/or short sampling times, these are ideal. They can be activated whenever important sampling is needed and many samples can be taken during a day. The problem is the associated laboratory time spent counting particles is large, and the analysis still is an average of the time interval (although short, results are not instantaneous). [illegible] would probably be advantageous to have some available for special tests of localized fugitive emissions.

The most viable combination depends upon the strategy needed for measurement of the fugitive emissions. The best recommendations are as follows:

1. Pseudo duct strategy
    - A. Piezoelectric mass monitor
    - B. Andersen impactor
    - C. EPA train as backup and confirmation of mass monitor (also used for organic particulates).
2. Roof monitor strategy
    - A. Multiple hi-vols for TRC 4" filters
    - B. Multiple Andersen impactors
    - C. Piezoelectric mass monitor for special runs
3. Upwind-downwind strategy
    - A. Multiple hi-vols or TRC 4" filters
    - B. Multiple Andersen impactors

C. Piezoelectric mass monitor for special runs
D. Rotorod Adhesive Impactor for FP tracer tests and other special situations
E. Consider experimental Lidar test

APPENDIX F

EPA METHOD 5 DATA SHEET

FIELD DATA SHEET

(EPA Method 5 Sampling Procedure)

Firm Name ____________

Plant Location ____________

Test No. 10

Sampling Location Mold Pouring

Date 4-10-75

Tester W.M., G.P.

Pump No. 23

Orifice No. 04 ΔH = 1.86

Ambient Temp. 70 °F

Bar Press. ____________ "Hg

Probe Ident. No. 40 CP .871

Filter Ident. No. 107

Probe Diameter 3/16 in.

Assumed Moisture 0 %

Test Duration 30 min.

Traverse Point Interval 5 min.

Probe Heater Setting — amp.

Box Temp. Setting — F

Port -114-	Point	3 4 5 Time Min.	6 7 8 9 10 Velocity P in H_2O	12 13 14 15 H in H_2O	18 19 20 T_M in °F	23 24 25 T_M Out °F	26 27 28 29 30 P_{STACK}	32 33 34 35 T_{STACK}	40 41 42 43 44 45 Initial Meter Volume cu. ft.	50 PROBE	Pump Vac. in Hg.	Remarks
	1	5.	.95	.35	77	75	1.30	94	471.41	1		
	2	5.	.91	1.30	75	78	1.25	68	474.45	1		
	3	5.	.83	1.15	79	76	1.20	67	477.77	1		
	4	5.	.60	0.54	79	76	1.00	68	480.75	1		
	5	5.	.53	0.74	79	76	0.97	64	483.56	1		
	6	5.	.45	0.63	79	76	0.98	65	486.00	1		
									488.28	1		Final volume

APPENDIX G

CASCADE IMPACTOR DATA SHEET

CASCADE IMPACTOR DATA SHEET

Test Location
Test No. 18
Date 4-17-75
Test Time 30 min.
Operators G.P.

Equipment Identification:
Control Module 3
Probe CP = .902
Impactor GI
Nozzle Size 0.25"

Pump No. 8
Orifice No. 3 ΔH = .83
Ambient Pressure

Test Point Location Mold Pouring
Start of Test (Time) 12:44
Initial Meter Volume (Cu. Ft.) 705.05
Initial Average Meter Temp (°F) 73

Filters:	Filter No.	Initial Filter Weights (mg)	Final Filter Weights (mg)
Collection Paper 1	103		
Collection Paper 2	102		
Collection Paper 3	101		
Collection Paper 4	100		
Collection Paper 5	99		
Collection Paper 6	98		
Collection Paper 7	97		
Back-up Filter	134		

Velocity Pressure ΔP (in H_2O) 0.40
Orifice ΔH (in H_2O) 1.90
Stack Pressure (in H_2O) -0.93
Stack Temperature (°F) 73
End of Test (Time) 1:16
Final Meter Volume (Cu. Ft.) 727.98
Final Average Meter Temp. (°F) 73

APPENDIX H

IKOR CONTINUOUS MONITOR DATA SHEET

CONTINUOUS PARTICULATE MONITORING (IKOR)
DATA SHEET

Test Location Mold Pouring
Test No. 11
Date 4-14-75
Test Time 11:57 12:27

Equipment Identification:
Control Unit EPA # 102515
Sensor Model 206
Probe "

Operators W. Marrone

Time Min.	Port	Point	Stack ΔP in H_2O	Probe ΔP In H_2O	Stack Temp. °F	Sensor Temp. °F	Time Constant (Sec.)	Sensitivity	Instantaneous Mass Flow M_s	Integrated Mass. Read. M_i	Back-Up Filter No.
0	1	1	.78	.78	80	80	100	10	2	0	9
3.5	"	"	"	"	70	70	"	"	1	4	"
12	"	"	"	"	"	"	"	"	.5	10	"
25	"	"	"	"	"	"	"	"	"	14.5	"
30	"	"	"	"	"	"	"	"	"	16	"

APPENDIX I

HI-VOL FILTER TEST DATA SHEET

HIGH VOLUME FILTER TEST

DATA SHEET

4-8-75

EQUIPMENT IDENTIFICATION	LOCATION	FILTER NUMBER	TIME START	INITIAL VOLUME FLOW	TIME END	FINAL VOLUME FLOW
HV-2	Booth	11153	12:23	46 Roto 6052	3:41	34
HV-3	Product. Area	11152	12:25	62 Roto 8563	3:38	40

APPENDIX J

LABORATORY WORKSHEET FOR FIELD SAMPLES

LABORATORY WORKSHEET
FOR
EPA FUGITIVE EMISSION STUDY
PROJECT 32397-04

Test Location ____________________

Test Date 4-10-75

Sent By N. Grappone

Reported To W. Marrone

Identification		Sample Description	Analysis Required	Special Comments
Test No.	Sample No.			
8	121	Membrane Filter	wt., sizing	EPA train
"	96	Probe wash	wt.	"
"	16	Condensibles - Inorganic	wt.	"
"	150	Condensibles - Organic	wt.	"
"	5	Silica Gel	wt.	"
"	6	Ikor Filter	wt	Ikor

APPENDIX K

CONVERTING UNITS OF MEASURE

EPA policy is to express all measurements in metric units. When implementing this practice will result in undue cost or lack of clarity, conversion factors are provided for the non-metric units. Generally, this report uses British units of measure. For conversion to the metric system, use the following conversions:

To convert from:	to:	Multiply by:
acfm	nm^3/hr	1.70
°F	°C	Subtract 32, then divide by 1.8
ft	m	0.305
ft/sec	m/sec	0.305
gal/mcf	l/m^3	0.134
gpm	l/m	3.79
gpm/ft^2	$l/min/m^2$	40.8
gr/scf	gm/m^3	2.29
in	cm	2.54
in H_2O	mm Hg	1.87
lb moles	gm moles	454
lb moles/hr	gm moles/min	7.56
lb moles/min	gm moles/sec	7.56
tons	kg	907.2